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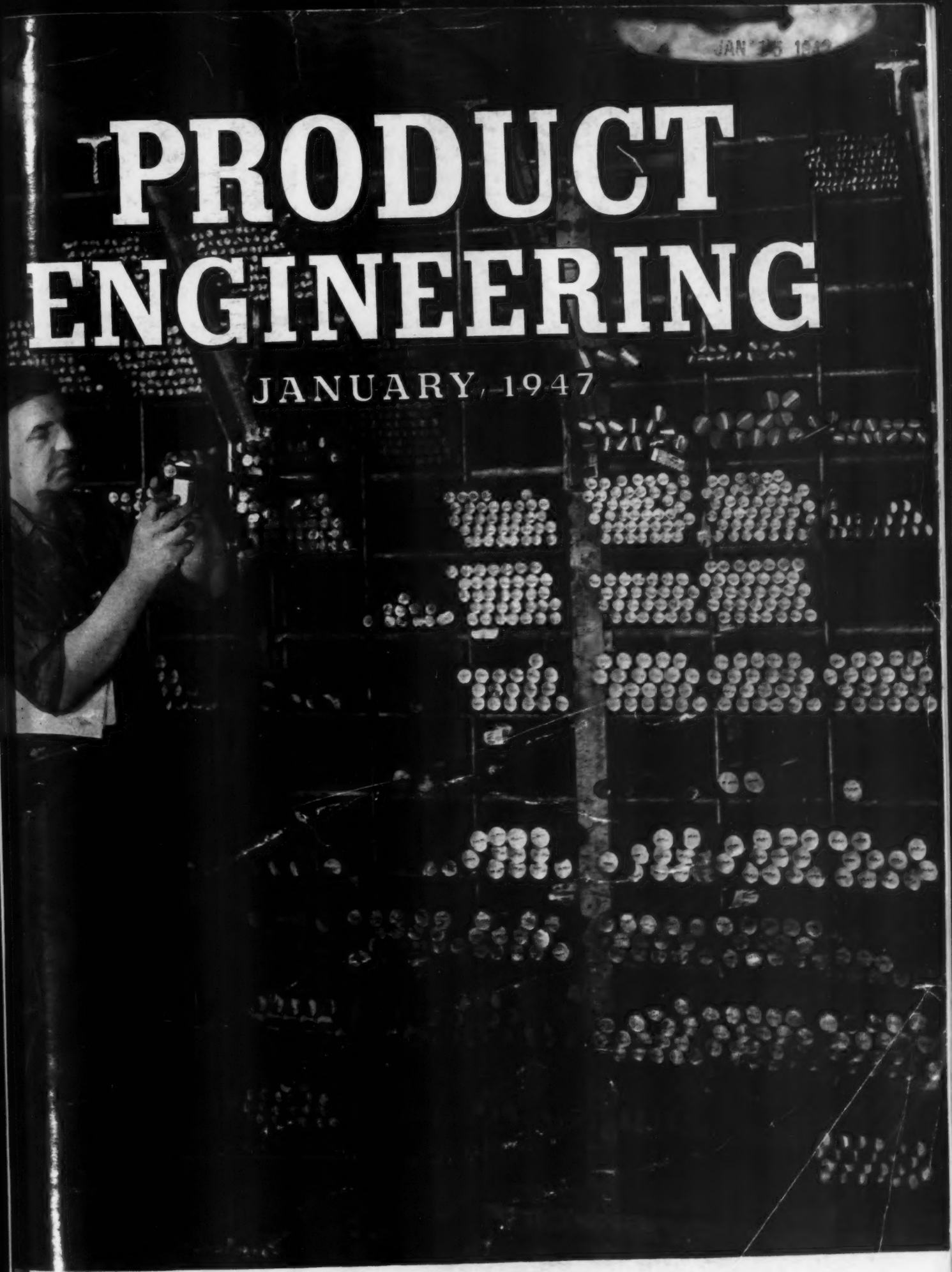
PRODUCT ENGINEERING

JANUARY, 1947



IN THIS ISSUE—Popular Types of Steels + Strain Measuring Devices + Rubber Linings to Protect Steel Parts + Electrical Indicating Instruments + Dimensioning Tolerances

CHROMIUM-NICKEL AUSTENITIC STAINLESS STEELS

Most versatile of modern metals . . . their unique combinations of properties merit your consideration in designing for the future.

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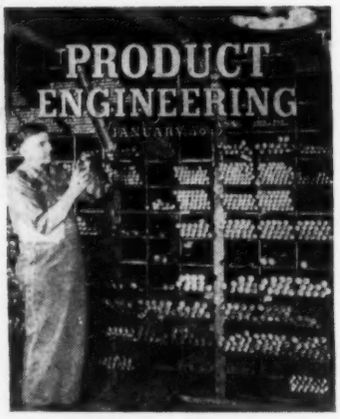

FRONT COVER

A standard color marking system to identify various types of alloy steel is used in many steel warehouses. The cover Kodachrome was taken in the Jersey City warehouse of Joseph T. Ryerson and Son, Inc.

Availability of Steels

The current steel shortage is making headaches for the design engineer. Procurement of any but the most popular steels is exceedingly difficult. On page 81, G. D. Boyer, metallurgist of the La Salle Steel Company, lists the most popular steel types and their characteristics in the hope that procurement will be simplified through their specification. Fabrication and heat-treating properties of popular steels are discussed.

Electric Motors in Airplanes

Indicative of the trend towards increasing use of electric motors in aircraft are the approximately 140 motors in a single B-29. On page 86, T. B. Holliday, president of Mueller Accessories, Inc., discusses the reasons for the trend toward more motors, use of higher d.c. voltages and 400 cycles for high power in aircraft. Limitations of electric motors and the need for standardization are covered.

Plastics Testing and Performance

Can mechanical tests developed for one material be used to evaluate other materials? H. M. Quackenbos, Jr., Research and Development Department, Bakelite Corporation, states on page 113 that conventional test methods for plastics, based on those originally developed for metals, are proving to be unsatisfactory in many applications. The impact tests give especially unreal values, and Mr. Quackenbos proposes modifications that he claims will have better relation to actual practice.

Designing for Economy

What must the design engineer know about production economies? This is a vital question that affects mechanical design since one product can often be produced by many different production methods, and the difference in cost will very often decide which method is chosen. Beginning on page 132 Kenneth W. Schmidt, Production Design Engineer of North American Aviation compares costs of production methods such as castings vs. forging, and extrusion vs. rolling.

Cardboard Mock-Ups

Popularity of mock-ups is increasing because of the design flexibility that is obtained from three dimensional planning. Heretofore, mock-ups have been constructed of wood, plaster or plastics. On page 120 Morton P. Matthew discusses the use of cardboard as a low cost and practical medium from which mock-ups can be constructed without outside aid in engineering offices.

Strain Measuring Devices

Considerable money and effort are frequently wasted through lack of information as to what is commercially available in strain-measuring devices. Often a combination of one of these instruments and a little adaptive ingenuity can materially simplify a problem in strain measurement. Types of strain gages, their limitations and fields for which each type is specially suited, are analyzed on page 107 by Karl F. Smith of the Battelle Memorial Institute.

Rubber Linings Insulate Steel

Where protection of ferrous metals against corrosive liquids or gases is a factor, rubber linings offer one solution. Engineers who design process machines, such as equipment for the pickling of steel, will find design data for lining such equipment with rubber on page 142 given by O. S. True, sales engineer of United States Rubber Company.

Electrical Indicating Instruments

Principles used in electrical indicating instruments are the basis of much of the measurement technique in industry. On page 123, L. F. Parachini, engineer of the Weston Electrical Instrument Corporation, discusses the fundamental mechanisms and characteristics of indicating instruments and principal accessory devices. Included are moving iron, electrodynamometers and permanent magnet coil types.

Dimensioning and Tolerances

Notwithstanding their basic importance in interchangeable manufacture, often not enough attention is given to dimensioning and tolerances. On page 160 Merhyle F. Spotts, Associate Professor of Machine Design, Northwestern University, outlines in the first of two articles, the relative advantages of unilateral, bilateral, cumulative, and non-cumulative tolerancing. Selective assembly for small toleranced parts and the use of datum surfaces is explained.

FEBRUARY HIGHLIGHTS

Precision Snap-Acting Switches, by A. L. Riche, vice president of Micro Switch. What they are and how to apply them. Discussion includes operating principle, key operating characteristics, and electrical and mechanical factors.

Trolley Conveyor Design and Application, by Sidney Reibel, Design Consultant, Albert Kahn Associated Architects and Engineers, Inc. Basic considerations in selecting the right trolley and methods of calculating safe loads.

Effect of Mechanical Design on the useful life of electrical contacts, by R. B. Immel, control design engineer, Westinghouse Electric Corporation. Analytical comparison of three different mechanical designs for an electrical contactor.

PRODUCT ENGINEERING *Editorial*

JANUARY, 1947

Expositions Are Being Overdone

TWO "metals shows" in ten months; four "plastics shows" in sixteen months! Who benefits? The metals exposition held last February in Cleveland had a relatively big attendance and included some reasonably new exhibits. The "show" at Atlantic City in November had relatively few metals exhibitors and was considerably "padded" with metals cutting, heat-treating and materials handling equipment. Despite figures reported, attendance was poor as compared to other expositions. Those who were absent didn't miss much; few new items were on display.

In the field of plastics, the Society of Plastics Engineers and the Society of the Plastics Industry are each planning expositions, both to be held in Chicago; in January and May respectively. Two such shows were held during the past year. Admittedly, great strides are being made in the field of plastics but the speed of new developments is certainly not such that it warrants two expositions in five months.

The original purpose of expositions was to provide a meeting place where manufacturers could show and demonstrate their new wares to prospective purchasers. In some instances this laudable objective has apparently been supplanted by the profit motive. Shows are repeated too often; few really new or appreciably improved things are exhibited. Those who have come a long way at considerable expense to "see what's new" get little for their time and money.

Trade shows should be carefully planned and timed by the industry association of the manufacturers concerned. An exposition should not be held if there are not enough new developments to warrant it. In the final analysis, it is the fault of the industries concerned if expositioning is overdone.

G. F. Rodenholtz

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HYDRAULIC CONTROLS

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- **BETTER WORK FINISH**
- **SIMPLICITY OF INSTALLATION**
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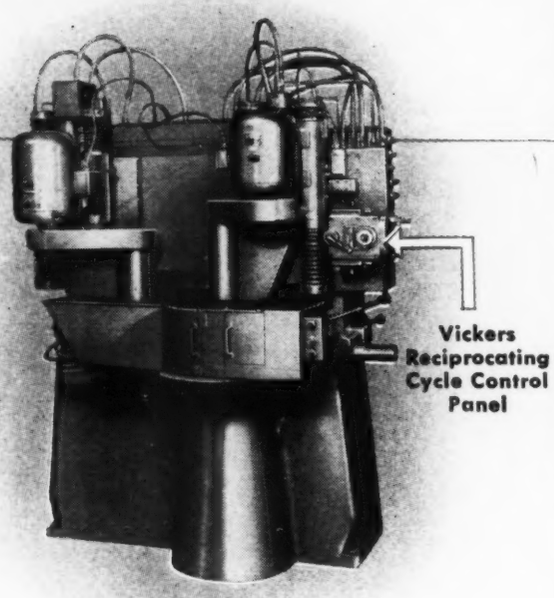

Springfield Special Purpose Grinder

The manufacturer has utilized Vickers Hydraulic Controls on this special purpose grinder to provide an important increase in production, better work finish, simpler operation, and protection for the operator, machine and work.

The machine grinds the backface and bore of the ring gear in one setup. Each grinding wheel is reciprocated hydraulically in proper sequence. All phases of machine cycle operation are interlocked hydraulically to prevent damage to work and machine.

Vickers Reciprocating Cycle Control Panel provides smooth reciprocation of grinding wheel, thus providing better finish. Stroke lengths are adjustable and maintained accurately thus eliminating unnecessary and time-consuming overtravel for a specific setup. Adjustable speed hydraulic drive of work spindle makes possible the best combination of speeds for better finish.

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A Vickers Application Engineer will be glad to discuss with you how hydraulic controls can be used to advantage on your products. Get in touch with nearest office listed below.

This is one of a series of applications pointing out the many advantages of Vickers Hydraulic Controls.

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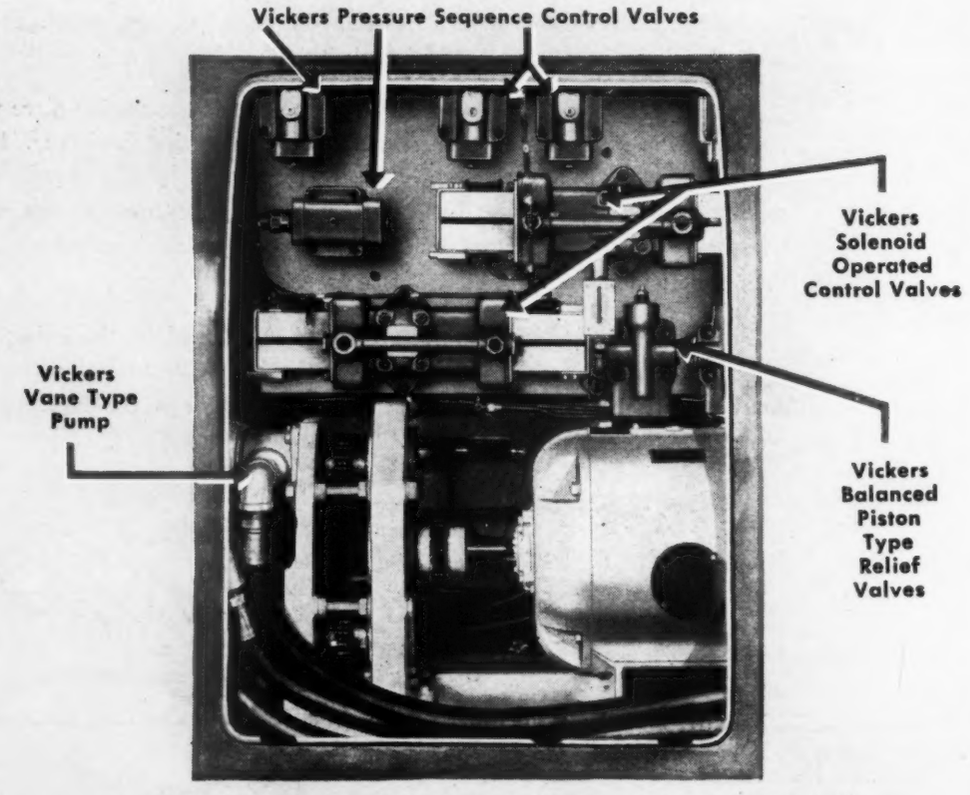
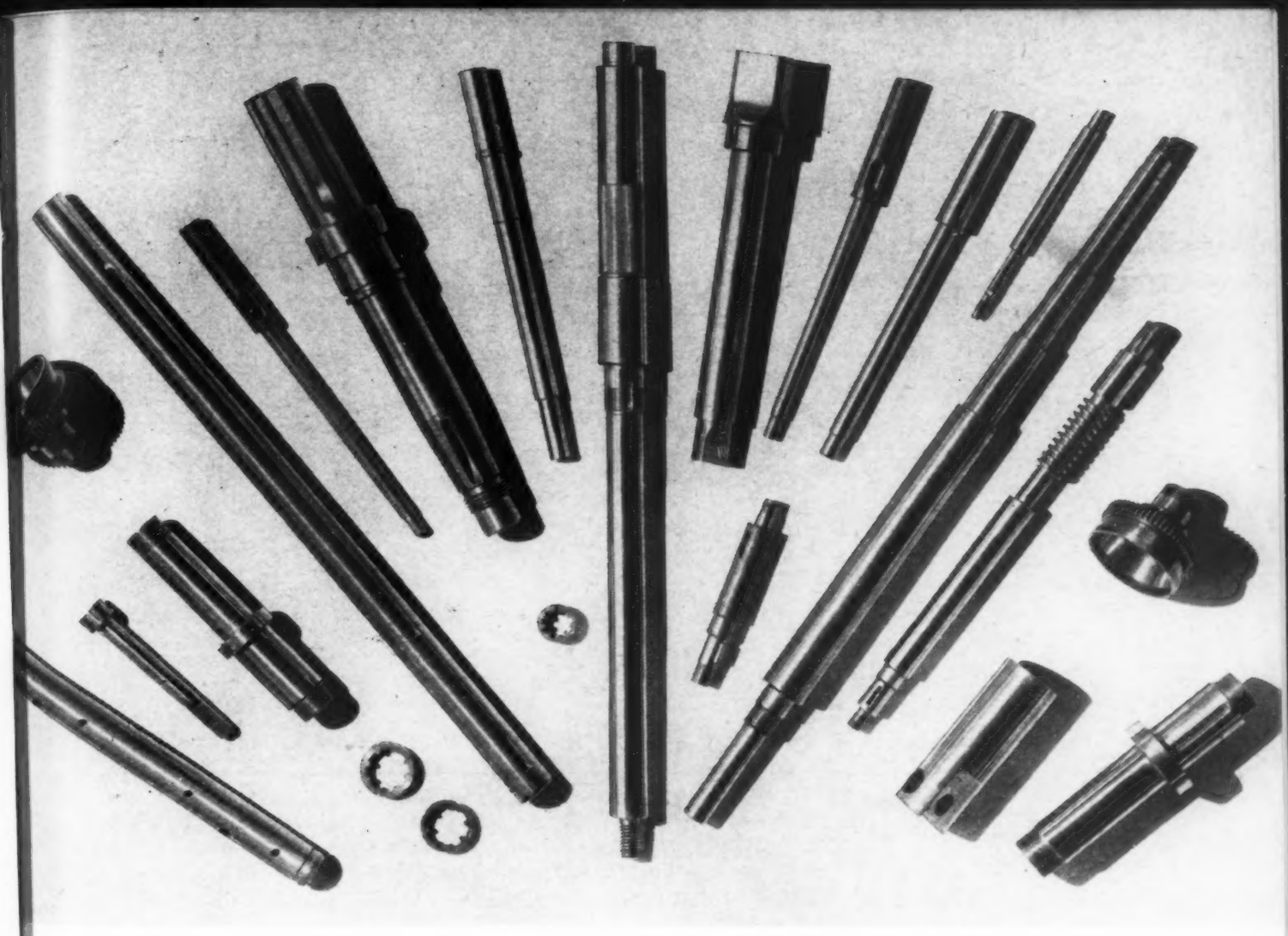
ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921



Rear View of Springfield Grinding Machine with Cover Plate Removed



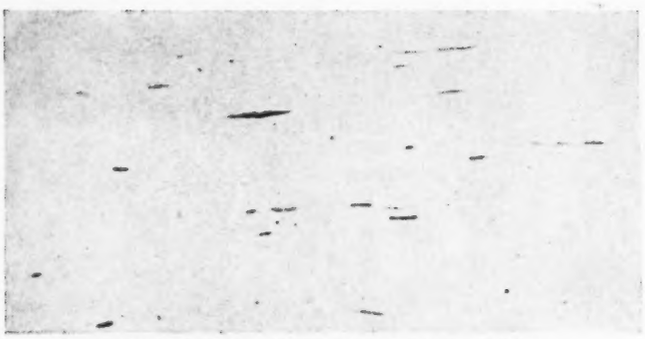
Popular Types of Steels

G. D. BOYER
Metallurgist, The LaSalle Steel Company

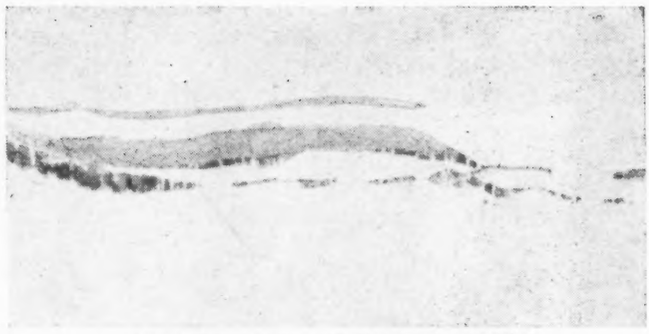
Discusses the current trends towards standardization in the specification of bar stock steels for use in the manufacture of industrial products. Points out the desirability of standardizing on the most popular steels to minimize procurement difficulties. Discusses the machinability characteristics of the various steels.

DESIGN ENGINEERS are currently faced not only with the problem of specifying materials that have the necessary physical characteristics to permit them to function properly but also with the problem of specifying, wherever possible, materials that are readily obtainable. In normal times, the steel mills produced a variety of steel types so that any individual consumer could obtain the type of steel he felt was best suited to his particular needs. The present shortages of steel, however, have forced the steel mills to concentrate on the production of a relatively limited number of analyses to achieve maximum production. Thus, it has become necessary for the designer to consider availability of materials as well as performance and economy in deciding on the material specifications for any given product.

The statements concerning the trends in steel production made in this article are based on observations of current practices in numerous steel consuming industries and of the problems of the steel industry in attempting to reconcile maximum production to maximum flexibility in regard to the variety of steels available. These trends have been influenced by both the alloy conservation efforts necessary during the war period and by the tremendous ad-

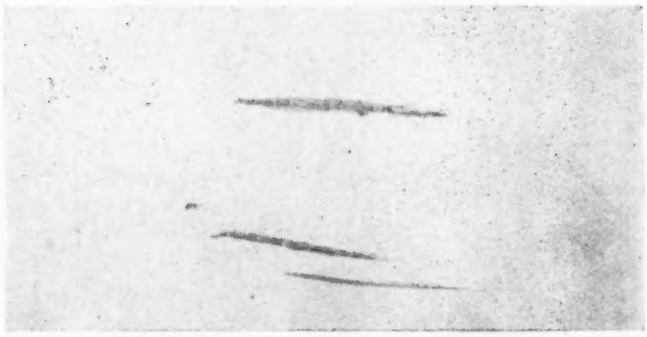


A8640 Sulphite Treated Not Etched 500X



C1144 Re-sulphurized Not Etched 500X

A8640 Non-resulphurized Not Etched 500X



C1040 Non-resulphurized Not Etched 500X

Non-metallic content of sulphurized and non-sulphurized alloy and plain carbon steels.

vances in metallurgical knowledge made in the past few years.

The various types if steels discussed are identified in accordance with the American Iron and Steel Institute's system of steel identification, since it appears that the A.I.S.I. system will be most commonly used in the future. The Society of Automotive Engineers have adopted this same system except for the prefix letter. This prefix letter fulfills a need since it indicates the method of manufacture or general class of the steel. "B" indicates Bessemer steels, "A" indicates alloy steels. "C" and "E" indicate carbon and electric furnace steels.

Trends in Carbon Steels

For applications requiring a medium carbon bar stock or shafting steel, C1040, C1042 and C1045 will be used as they have been in the past. However, C-1042 is replacing C-1040 and C-1045 as the most commonly used medium carbon shafting steel. It is identical to C-1040 and C-1045 except for its carbon content, which is 0.40 to 0.47 percent. C-1042, which is actually an average of C-1040 and C-1045, has been developed to combine the better features of these two steels, and to minimize their weaknesses.

In regard to the machinability of these three steels, C-1040 is about 55 percent of B-1112 or 90 surface ft. per min., while C-1045 is 51 percent, or 84 surface ft. per min. The lower rating for C-1045 is largely caused by occasional high side chemistry heats that are often too hard for good machinability. C-1042, with a maximum ladle carbon content of 0.47 percent, is much less liable to this hardness and so warrants a 55 percent and 90 surface ft. per min. rating.

Large tonnages of these medium carbon steels are used in the "as cold-drawn" condition for shafting and other products that require a certain moderate strength and hardness. Table I lists the average physical properties of these steels as cold-drawn one inch rounds. These data show that there is no essential difference between the three steels.

All three are classed as water quenching steels. For applications where close hardening limits are not necessary, they are usually satisfactory. For applications where high surface hardnesses or any great depth of hardness is required, either by induction or conventional methods of hardening, none of these steels is satisfactory. Instead, depending upon the particular application, the use of C-1050, or an alloy steel, is indicated.

A number of the leading warehouses in the Middle West have standardized on C-1042 steel so that they can be assured of a steel that averages the characteristics of the class, that will harden better than a low side C-1040 and is not liable to the machining difficulties of a high side C-1045. This trend should continue.

For low carbon shafting and carburizing steel C-1019 should continue to be generally used. An old steel with a new name, C-1019 was introduced in 1929 under the trade name of 1020-90 to replace the old S. A. E. 1020 steel. It was later recognized as S. A. E. X-1020 with its variant S. A. E. X-1015. Its carbon content of 0.15 to 0.20 percent averages that of C-1016 and C-1022 and is actually identical to the formerly aimed range of both S. A. E. X-1015 (0.10 to 0.20 percent carbon and S. A. E. X-1020 (0.15 to 0.25 percent carbon).

The higher manganese content (0.70/1.00) of C-1019 is responsible for its greatly improved machinability and carburizing properties as compared to S. A. E. 1020. When made to a controlled grain size, C-1019 is dependably uniform in carburizing properties, approaching even the alloy steels in this respect. C-1019 has

somewhat better physical properties than C-1020 and can be rolled with a minimum of surface defects.

For certain applications the lower carbon of C-1016 may be desirable and in other applications the higher carbon C-1022 might be a better choice. But for the great majority of parts for which a low cost carbon steel with ready machinability is required, it seems certain that C-1019 will continue to be selected.

Limited in use at the present time, C-1050 may easily become a steel of great importance because it is the steel with the lowest carbon content that can be hardened to a fully martensitic structure in induction hardening. However, since in the "as cold-drawn" condition it is often too hard for easy machining and usually requires an annealing or strain relieving treatment it is unlikely to replace C-1042 as a general all-purpose shafting and machining steel.

Free Machining Steels

Sulphur has long been added to carbon steels, usually in conjunction with manganese, to produce better machining characteristics. Without a doubt this practice will continue. Through the years, the popular grades of these steels have been C-1117 (formerly S. A. E. X-1314), C-1118, C-1137 (the old S. A. E. X-1335) and now the newer C-1144.

Identical except for a slight manganese variation, C-1117 and C-1118 are very similar steels. Both are fast machining and have good carburizing qualities. The slightly better machinability of C-1117 (142 surface ft. per min. as compared to 133 surface ft. for C-1118), together with the fact that it offers fewer manufacturing problems has contributed to the extensive use of C-1117 in the past, and probably will continue to do so.

Considerable interest has been shown recently in such steels as C-1113 and C-1217 because of the extreme shortage of Bessemer steels. These are actually special purpose steels valuable for particular applications. As general purpose steels they are basically substitutes for the more standard materials, particularly since C-1113 and C-1217 are not generally available.

One of the old time steels, C-1137, came out of the war with a greatly enhanced reputation. Long used as a quenching steel because it has better hardenability and machinability than the straight carbon steels, its use in the cold-drawn and strain-relieved condition for 20mm., 37mm. and 40mm. shell bodies popularized it still more. Without doubt, it will remain one of the basic steels of the industry.

The best combination of machinability and hardenability of the carbon steels is offered by C-1144. It has sufficient carbon to permit hardening to a minimum of Rockwell C-56 by induction hardening yet it machines at a rate of 79 percent of B-1112 as cold-finished and at 85 percent as cold-finished and strain-relieved. It is primarily a heat-treating steel that is chiefly used for gears, worms, splines and similar parts that require considerable machining and induction hardening.

Despite the present extreme shortage of Bessemer steels, which is causing an intensive search for any available substitute, steels made by the Bessemer process will continue to be the basic material for the production of low cost screw machine parts. There is no substitute for them. B-1112 and B-1113 are the most popular of these steels.

The choice between B-1113 and B-1112 depends largely on conditions in the screw machine shop. B-1113 costs a little more per hundred weight. If the machines cannot be speeded to take advantage of the increased machinability (140 to 180 percent of B-1112) then, of course, the preference is given to the lower priced B-1112. But, when conditions do permit the full utilization of the machinability of B-1113, it is the best of the free machining steels.

The trend has been toward higher and higher sulphur contents. However, it appears that the present B-1113 has about the highest sulphur content (0.24 to 0.33 percent) that is now practical from a production standpoint.

Trends in Alloy Steels

The trends in applications of alloy steels are far from clear. A period of reorientation has been injected into the alloy steel situation as the result of knowledge gained on new alloy grades developed during the war and of additional experience on the multitude of grades that were an integral part of prewar practices.

For example, a user of large quantities of cold-finished alloy steels has made three major changes in alloy specifications since the war. Before the war this company used a resulphurized S. A. E. 4145. During the war they were forced to a considerable extent to use any grade available but finally standardized on sulphite treated A-8640. Following the war they used sulphite treated A-4340, then regular S.A.E. 4145 and A-4340, but have finally returned to sulphite treated A-8640. This is an extreme example, but it does illustrate the state of flux prevailing today.

This state of flux is caused largely by the impact of the ternary N.E. steels. While there was little change in the carbon steels during the war, these ternary alloys are new and, as yet, not completely assimilated. Actutally these alloys, particularly the A-8600 series, have worked well and are here to stay.

The main advantage of these ternary alloys over the binary and single alloy steels is that they have no uncontrolled residual alloy contents. Practically all the scrap now

Table I—Physical Properties of Cold-Drawn Medium Carbon Steels

Steel type	C-1040	C-1042	C-1045
Brinell hardness	192	196	202
Tensile strength, lb. per sq. in.	99,750	101,000	102,500
Yield point, lb. per sq. in	92,000	92,750	93,450
Reduction of area, percent	54.6	53.8	52.5
Elongation in 2 in., percent	15.1	15.0	14.8
Maximum shearing stress, lb. per sq. in.	85,000	86,000	86,400
Elastic shearing stress, lb. per sq. in.	36,000	36,400	36,800
*Maximum twist in 10 in., deg	2,504	1,495	1,485
*Elastic Twist in 10 in., deg.	5.4	5.5	5.6

* Tests made on 1 in. dia. rounds.

available for steel making contains appreciable quantities of nickel, chromium and molybdenum. Consequently, an unpredictable quantity of residual alloy is likely to show up in any heat of steel.

Because the three chief alloys are all specified and controlled in the A-8600 steels, the alloy content of the scrap is unimportant since the final alloy additions are made on the basis of the residuals. This makes the production of these steels attractive to the steel makers since they can take advantage of a condition that would otherwise be a detriment.

For applications requiring a carburizing grade of alloy steel, A-8617 and small quantities of A-8620 are almost the only steels specified on current orders and inquiries. There is a little A-4615 used for special purposes but only little use of the other carburizing alloys.

In regard to the quenching alloys, although there are large quantities of the older alloys such as A-4140 being used, most of the orders are for A-8640, particularly sodium sulphite treated A-8640. This trend appears to be continuing.

The introduction of the sodium sulphite treatment of alloy steels is having a far reaching effect. For many years, sulphur has popularly been thought to be deleterious to steel. However most metallurgists believe that it is iron sulphite and not sulphur that is the offender and that if sufficient manganese (from five to ten times the amount of sulphur) is added to keep the sulphur in the form of manganese sulphide, it is not harmful. The sulphite treatment process goes a step further. When added to molten steel, sodium sulphite decomposes to form sodium oxide and sulphur dioxide. The sulphur dioxide goes into the steel to be retained as manganese sulphide while the sodium oxide fluxes high melting point non-metallics out of the bath thus producing a cleaner steel with fewer abrasive inclusions. This treatment adds 0.02 to 0.03 percent sulphur that, together with the normal residual sulphur, produces a steel of about 0.045 to 0.05 percent sulphur, which is about the usually specified upper limit for the element in non-resulphurized steels.

Repeated tests have shown no difference between the physical properties of sulphite treated steels and those of non-resulphurized steels. This is probably because the manganese-sulphur ratio (0.75/1.00 percent Mn to 0.05 percent S) is high. The sulphite treatment increases machinability about 25 percent and tool life possibly more because of the freedom from hard inclusions as well as because of the sulphur itself.

In connection with alloy steels it is interesting to note the present reversal of the long time trend from alloy steel to carbon steel. The pressure to reduce costs has heretofore been responsible for the continual replacement of alloy steels with the lower priced carbon steels through the development of better hardening characteristics in carbon steels and refinements in heat-treatment practices. But now since alloy steels are more available than the carbon steels, the substitutions are in the other direction.

Actually, in many instances the trend to carbon steel has been overdone. While carbon steel prices are lower than those of alloy steel, and usually its machining costs are less, the cost of intricate heat-treating set-ups, and inspection routines, may out-weigh the initial economies.

For instance, it may often be possible to "mass quench" alloy parts where individual quenching would be required for carbon steels. Also, in an application where the hardenability of the carbon steel is borderline, increased inspection and higher percentages of rejections must be anticipated. However, as soon as the carbon steels become readily available, the former trend will be resumed.

The pressure to reduce costs, coupled with the enforced use of lean alloys during the war, is resulting in a critical examination of the use of the highly alloyed steels, and in many applications the lower priced lean alloys have been found to be completely adequate. For special applications, there will always be a place for these more expensive steels but they will not be specified in the future as freely as they have been in the past.

Table II—Recommended Standardized Steels for General Machining

Application	Steel
Medium carbon shafting	C–1042
Low carbon shafting	C–1019
Carburizing steel	C–1019
Carburizing alloy steel	A–8617
Induction hardening	C–1050
General purpose hardening	C–1144
Hardening, alloy grade	A–8640
Low carbon, free machining	C–1117
Medium carbon, free machining	C–1137
Hardening, free machining	C–1144
Screw machine stock	B–1112–B–1113

There should be a continuance of the use of "heat-treated in the bar" steels, which are usually made to the requirements of ASTM specification A-96-39 "Alloy Steel Bolting Material for High-Temperature Service." Since these steels are sold mainly on physical property specifications, the steel producer has been allowed considerable latitude in the choice of chemistry. Standardization on sulphite treated A-8640 for "heat-treated in the bar" steels is advantageous because many applications of these steels such as axles, shafts and bolts entail considerable machining. The approximately 25 percent added machinability produced by the sulphite treatment does much to overcome the machining difficulties normally encountered in these strong tough steels, which necessarily possess a poor metallographic structure for machining.

It is practically certain that the trend toward cold-drawn and cold-drawn and strain relieved steels to definite guaranteed physical properties will be greatly accelerated as soon as the immediate reconversion problems of the industry are settled. Considered as specialties before the war, the tremendous increase of strain relieving capacity in the various steel mills, coupled with the experience gained both by the producers and consumers with these definite physical property steels during the war should make them commonplace in a few years.

There are two classes of these steels. In one class special drawing, with or without subsequent furnace treatment, is employed with some regular analysis to produce a bar for a particular purpose. Such was the shell body steel made from strain relieved C-1137 steel. This class of steels is suitable for large tonnage applications.

The other class employs a special steel with special chemistry, drawing, or furnace treatments to produce

Table III—Analysis, Machinability and Alloy Extra Costs of Popular Bar Stock Steels

	C	Mn	P	S	Si	Ni	Cr	Mo	Machinability percent of B-1112 (165 SFM)	Analysis extra† $per cwt.
C-1016	0.13/0.18	0.60/0.90	0.04 max.	0.05 max.					73	0
C-1019	0.15/0.20	0.70/1.00	0.04 max.	0.05 max.					73	0
C-1022	0.18/0.22	0.70/1.00	0.04 max.	0.05 max.					70	0
C-1040	0.37/0.44	0.60/0.90	0.04 max.	0.05 max.					55	0.10
C-1040	0.40/0.47	0.60/0.90	0.04 max.	0.05 max.					55	0.10
C-1045	0.43/0.50	0.60/0.90	0.04 max.	0.05 max.					51	0.10
C-1050	0.48/0.55	0.60/0.90	0.04 max.	0.05 max.					48	0.10
B-1112	0.08/0.13	0.70/1.00	0.07/0.12	0.16/0.23					100	0.10
B-1113	0.08/0.13	0.70/1.00	0.07/0.12	0.24/0.33					135	0.175
C-1113	0.10/0.16	1.00/1.30	0.045 max.	0.24/0.33					103	0.35
C-1117	0.14/0.20	1.00/1.30	0.045 max.	0.08/0.13					85	0.20
C-1118	0.14/0.20	1.30/1.60	0.045 max.	0.08/0.13					82	0.20
C-1137	0.32/0.39	1.35/1.65	0.045 max.	0.08/0.13					73	0.35
Mod. C-1144	0.40/0.48	1.35/1.65	0.045 max.	0.20/0.32					79	0.45
C-1217	0.14/0.19	0.70/1.00	0.09/0.13	0.20/0.29					130	0.25
A-4140	0.38/0.43	0.75/1.00	0.04 max.	0.04 max.	0.20/0.35		0.80/1.10	0.15/0.25	*61	0.70†
A-4145	0.43/0.48	0.75/1.00	0.04 max.	0.04 max.	0.20/0.35		0.80/1.10	0.15/0.25	*57	0.70†
A-4340	0.38/0.43	0.60/0.80	0.04 max.	0.04 max.	0.20/0.35	1.65/2.00	0.70/0.90	0.20/0.30	*51	1.70†
A-4615	0.13/0.18	0.45/0.65	0.04 max.	0.04 max.	0.20/0.35	1.65/2.00		0.20/0.30	64	1.20†
A-8617	0.15/0.20	0.70/0.90	0.04 max.	0.04 max.	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25	64	0.65†
A-8620	0.18/0.23	0.70/0.90	0.04 max.	0.04 max.	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25	61	0.65†
A-8640	0.38/0.43	0.75/1.00	0.04 max.	0.04 max.	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25	*55	0.65†
A-8640 Sulphite	0.38/0.43	0.75/1.00	0.04 max.	0.07 max.	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25	*70	0.80†

* In annealed and cold-drawn condition.
† Does not include annealing extras for those steels usually furnished annealed. Also add 8.2 percent to extra for alloy (A) steels.

either a special purpose or a general all-purpose bar and is often sold under trade names. Thus a steel developed particularly for lead screws is a turned, high temperature strain relieved and ground bar of a modified C-1144 analysis. The same chemistry is employed in the manufacture of a patented bar steel but with a patented cold drawing and furnace treatment to produce a general all-purpose bar.

The first steel has excellent machinability (79 percent Bessemer B-1112) and almost complete freedom from warpage and growth during machining—two very desirable qualities in lead screw manufacture. The second, almost as machinable (76 percent) and relatively free from warpage, also has high strength (100,000 lb. per sq. in. yield point) and for its hardness a high degree of wear resistance.

One quality of all cold-finished and strain relieved bars possibly not too well known is their uniformity of hardness across the bar. It is unusual to find as much as 2mm. diameter of Brinell impression difference between the center and surface of even a 3 in. bar. A cold finished and strain relieved bar may have a center Brinell of 235 and a surface of 241 while, of course, a quenched and tempered bar in the larger sizes has a much greater spread. The reason for this is that both cold-drawing and strain relieving effect all parts of the bar equally and are not in any manner dependent upon quenching speeds as in the quenched bar.

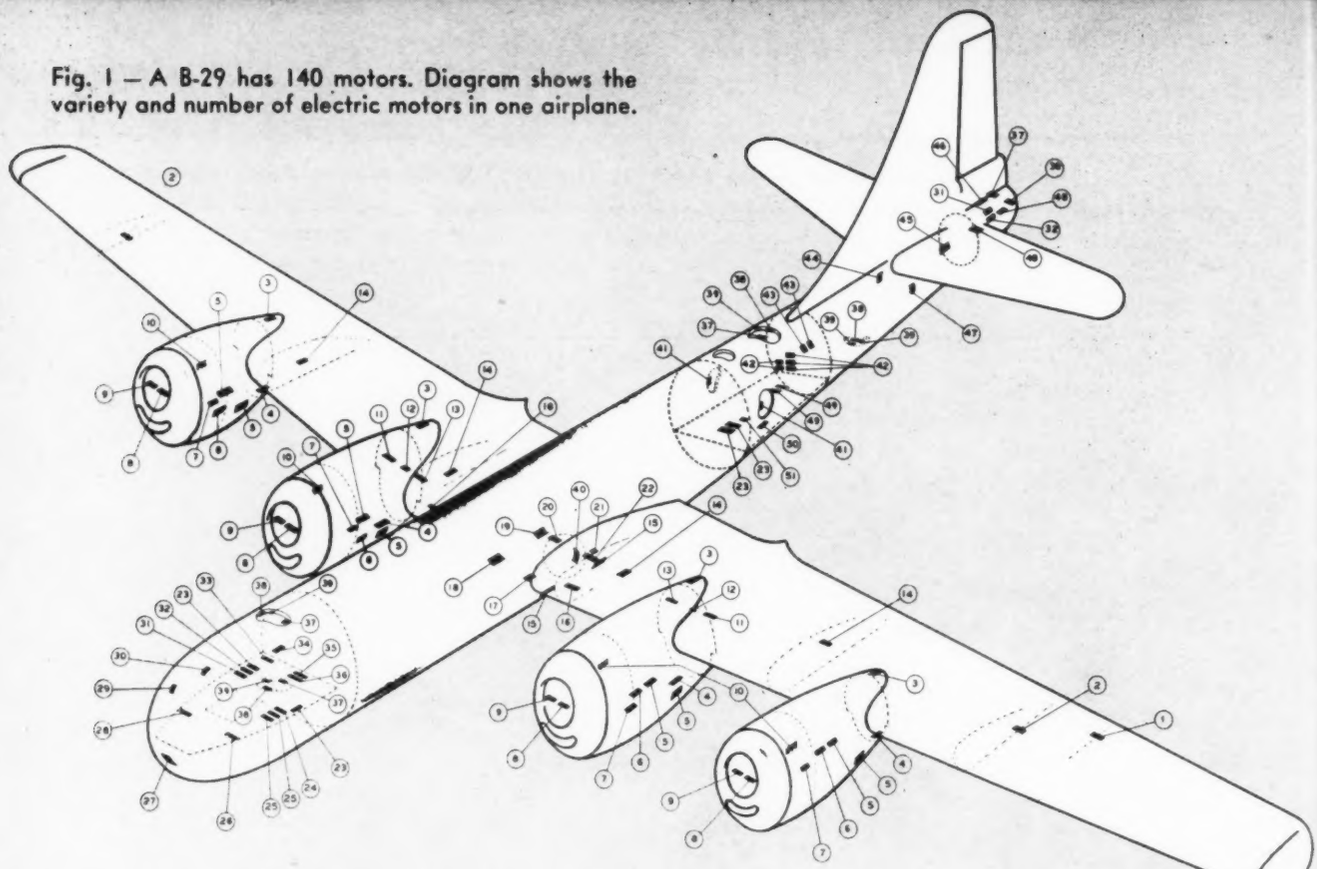
Standardization of Steels

Because of the extreme shortage of steel at the present time, there is fairly effective standardization, but to predict that this trend will continue when supply will equal demand is probably wishful thinking.

This is as much the fault of the producers as of the consumers. The tendency is as strong to magnify a small difference between two grades of steel in order to make a sale as it is for a consumer to cling to his old specifications no matter how special they are.

But it might be well to point out that standardization within a user's plant on the minimum number of grades and sizes is only part of a completely effective standardization program. To be sure, minimizing the number of grades and sizes is important and effective in reducing costs because of the resulting quantity discounts, lower inventories, and less likelihood of mixups. But, unless the standard steels chosen for a plant are generally popular, flexibility of supply will not be gained. Thus, good metallurgical arguments can be advanced for standardizing on on either C-1016, C-1019 or C-1022 as an economical low carbon car steel. But unless the most popular C-1019 is selected, the purchasing department will be limited for the most part to mill production orders to procure the steel. The other steels cannot be procured from the warehouses in an emergency and the steel mill cannot always divert steel from some lot going through production to help out.

Fig. 1 — A B-29 has 140 motors. Diagram shows the variety and number of electric motors in one airplane.



1. Flux Gate Compass Gyro Motor
2. Landing Light Motor
3. Intercooler Motor
4. Oil Coolant Motor
5. Supercharger Waste Gate Motor
6. Accelerometer Motor (Turbo)
7. Cowl Flap Motor
8. Prop Feather Motor
9. Prop Pitch Motor
10. Engine Starter Motor
11. Landing Gear Motor (Main)
12. Landing Gear Nacelle Door Motor
13. Landing Gear Motor (Emergency)
14. Fuel Boost Pump Motor
15. Fuel Transfer Motor
16. Heat Exchanger Motor
17. Deicer Time Motor
18. Forward Bomb Door Motor
19. Rear Bomb Door Motor
20. Aileron Servo Unit Motor
21. Portable Bomb Doors and Flap Motor
22. Wing Flap Motor
23. Dynamotor
24. Dynamotor Inverter
25. Amplidyne Motor Gen. Central Power Control
26. Main Nose Gear Motor
27. Bombsight Motor
28. Emergency Nose Gear Motor
29. Bombardier s Defroster Fan Motor
30. Pilot s Defroster Fan Motor
31. Amplidyne Azimuth Motor
32. Amplidyne Elevator Motor
33. Dynamotor Interphone
34. Trailing Antennamotor
35. Hydraulic Pump Motor (Normal)
36. Hydraulic Pump Motor (Emergency)
37. Azimuth Motor
38. Elevator Motor
39. Gun Charger Motor
40. Radar Dome Retracting Motor
41. Blister Defroster Fan Motor
42. Amplidyne Motor
43. Camera Motor
44. Rudder Servo Unit Motor
45. Tail Skid Motor
46. Ammunition Booster Motor
47. Elevator Servo Unit Motor
48. Air Compressor Motor
49. Inverter Motor
50. Prop Deicer Pump Motor
51. Fan Inverter Cooling Motor

ELECTRIC MOTORS FOR AIRCRAFT

T. B. HOLLIDAY*
President, Mueller Accessories, Inc.

THE approximately 140 motors in a single B-29 are indicative of the trend towards the increasing use of electric motors by aircraft. As shown by Fig. 1, electric motors perform a wide variety of tasks and are located all over the airplane.

The influence of aircraft thinking on electric motor design has been to obtain more power from each cubic inch of volume and each pound of weight. In only few instances has the ultimate power per pound been reached. The principal deterrent is the influence of commercial adaptations. In aircraft equipment the electric motor is expected to compete with hydraulic and pneumatic power. In no application has the electric motor excelled these competitors. Because hydraulic and pneumatic devices always have been designed to aircraft standards they have minimum weight.

Compared to hydraulic and pneumatic elements, the electric motor is a complicated device. The armature is a stack of sheet laminations. The commutator in a d.c. motor is an intricate assembly of copper wedges. Wiring is wound into slots and around poles. The whole is assembled in a frame that has reasonable accuracy. Despite this complication, a d.c. motor is low in cost. Much of this low cost results from using readily available commercial designs that can be produced in large volume and are merely adapted to aircraft requirements.

Most aircraft ordinarily use 12 or 24 volt d.c. motors. These motors are applied on intermittent or continuous duty cycle. Most intermittent duty motors produce torque for a short period of time. The series

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wound motor is ideal for this application. Most continuous duty motors drive pumps, fans, and motor generator sets. A compound wound motor is usually used, although the simple shunt wound motor is occasionally applied.

Direct current motors have had a big advantage because most applications in aircraft have required a high ratio of torque to current, such as produced by the series wound motors. However, the weight of the wiring in a low voltage system is excessive and the trend is towards the use of higher voltage d.c. motors. The higher voltage has little effect on the weight-power ratio of the motors, because weight is usually proportional to power. The higher voltage reduces the length and weight of the commutator, but adds certain electrical design problems in insulation and increased voltage between bars on the commutator.

Trend Towards High Frequency

There is also a trend towards high frequency a.c. motors for certain applications. In the small airplane alternating current is supplied by conversion from the low voltage, d.c. system to 115 volt 400 cycle alternating current by a motor generator set or an inverter. With this limited source of power a.c. motors seldom exceed 100 volt amp. in rating. For large aircraft, experimental investigations and tests are proceeding on a 208/120 volt 120 kw. 3 phase 400 cycle system. With this system there is opportunity to use motors of much higher horsepower ratings, including some 14 hp. motors. In addition to difficulties that are common to d.c. motors, the a.c. motors have the additional undesirable characteristic of power factor. Principally because of power factor, the torque per unit of current in a.c. motors is approximately half that in a series wound d.c. motor. Thus, for torque applications the d.c. motor is much superior. For continuous duty applications the disadvantage is less; and other advantages of weight, simplicity, efficiency, and lowered maintenance often make the a.c. motor the better choice.

Another factor that helps compensate for the disadvantage of power factor is the decreased vulnerability of a.c. motors. The three phase system has a grounded neutral in all-metal aircraft. If one of the three conductors is broken the motor still operates on two phases and delivers 80 percent of rated stalling and running torque. If two leads are cut, the motor can deliver 50 percent running torque for a short time.

Some Limitations

Any electric motor has several weaknesses. For example, a motor is weakest when needed most, such as when stalled or overloaded. If a hydraulic or pneumatic device is stalled, no particular harm is done. But when an electric motor is stalled the armature consumes approximately six times full load current and burns itself out within five seconds to five minutes depending on the design. Any motor that will not burn out under stalled condition is too heavy for use in aircraft. Measurable progress has been made in developing protective devices that prevent motors from burning out and the work is still going forward.

Another basic limitation of the electric motor is that its adjustable speed range is not great enough for many applications. In d.c. motors, control of the field current gives a 2 to 1 range of speed, control of armature current gives a 2 to 1 range and control of both provides a total of 4 to 1 speed range. An a.c. motor has very little speed adjustment. Since an infinite variation is needed in many applications, particularly servo drives, it is always necessary to place a variable ratio coupling between the a.c. motor and the driven device. This is a weight and design handicap to the electric motor when competing with hydraulic devices for servo applications.

Another limitation of the electric motor is that its high speed makes it impractical to position devices accurately by the motor alone. Allowance must be made for the "coast" of the rotating armature and since this coast will vary with the temperature, it is almost impossible to position a driven device accurately. This makes necessary auxiliary clutches and brakes, or a combination of both, to separate the motor from the driven device. This lets the driven device be positioned exactly and prevents the free wheeling of the motor from affecting the position.

With d.c. continuous duty motors radio noise is an important problem. Navigation of aircraft is becoming increasingly dependent upon radio and radar. Electrical interference with this electronic navigating equipment cannot be tolerated. Too often the motor designer ignores this problem, produces a noisy motor and gives the aircraft electrical engineer a troublesome installation problem. The trouble can be corrected by shielding the motor behind metal walls, by careful routing of wiring, and by filtering. However, it has been thoroughly proven that a noisy motor is a poor electrical design. The motor designer can give considerable help to the aircraft engineer of the plane if he first makes a good electrical design, and second, adds internal filtering to reduce noise to approximately 500 microvolts between the limits of 0.2 and 20 megacycles.

A final non-electrical handicap is that there is little standardization in electrical motor design and use. The Army Air Forces cooperating with the Bureau of Aeronautics is attempting to obtain some standardization of mounting bases and flange dimensions, service conditions, ratings, and similar basic considerations. The standard also recommends that the motor be usable in any position. Such standardization would be a definite advantage to the Army Air Forces because it would reduce the spare parts problem. When an airplane can be put out of commission by the failure of a single electric motor, standardization and protection assume importance hitherto unrecognized. These requirements have met little support from the motor industry, primarily because the lightest weight installation is obtained by designing a motor into the driven device.

Five Types of Application

A designer in using an electric motor for an aircraft application usually finds that his problem approximately falls into one of five categories. The first is a straight drive, such as a motor generator set or a fan. The driven device is coupled directly to the motor and usually the two parts are designed as an integral

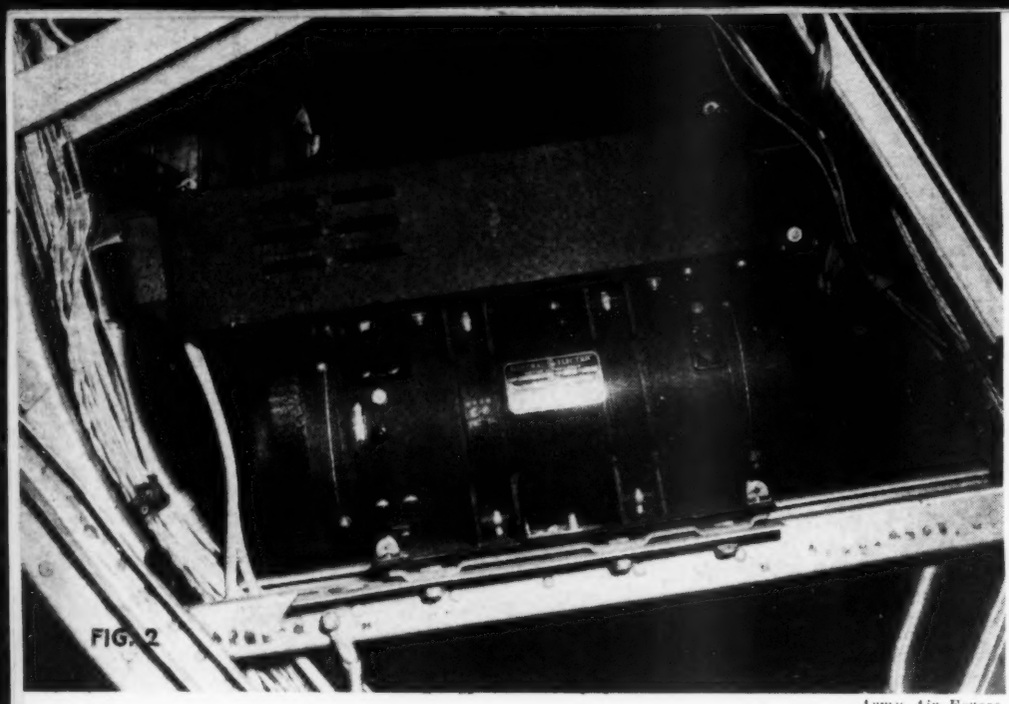

FIG. 2

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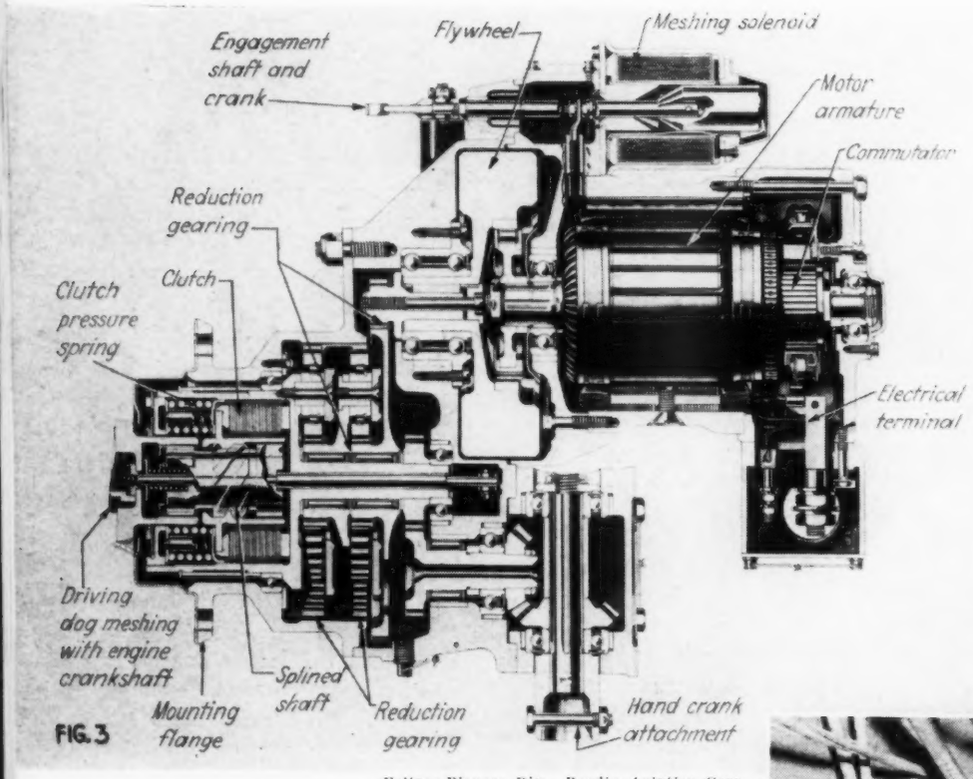

FIG. 3

Eclipse-Pioneer Div., Bendix Aviation Corp.

unit to achieve minimum weight. Protection is least important in these designs since there is little possibility of locking the armature or other rotating part. A typical inverter or motor generator set is shown in Fig. 2. Note that the controls for voltage and frequency combined with radio noise filter occupy a box of size almost as big as the inverter. In motors of this size, properly grounding the negative lead is a serious problem to the aircraft electrical engineer. A typical engine starter is a more complicated drive and is shown by Fig. 3. The essential parts include a high speed electric motor, reduction gearing, a clutch and an engaging device. The flywheel in the assembly stores a large amount of kinetic energy that is used to accelerate the engine quickly to starting speeds.

A second type of motor application is for driving devices like pumps, Figs. 4 and 5. In Fig. 4, the coupling flange is the price paid for standardization of motor dimensions. A high speed motor with gear reduction is usually advantageous because the overall unit is lighter in weight. Integral protection against electrical burn-out is very important in these designs because locking of rotating parts can occur within the gear box, within the pump, or by corrosion and sticking of pump vanes that occurs during periods of idleness. Motor pump units are usually designed to supply fuel, oil or air under pressure. With fuel pumps, Fig. 5, the designer must use great care in supply-

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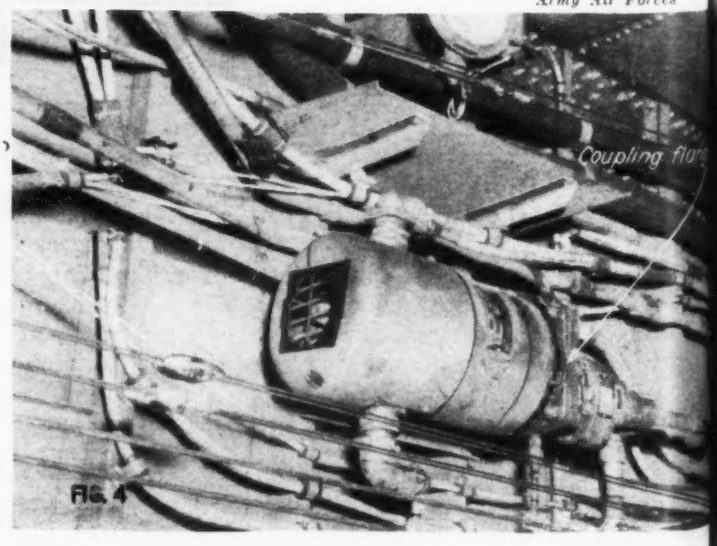


FIG. 4

Fig. 2—A 28 volt d.c. to 115 volt single phase 400 cycle motor generator set that supplies a.c. power to radio equipment. Box has filters and controls.

Fig. 3—Sectional view of an engine starter.

Fig. 4—Direct drive motor pump unit. Motor is heavier than usual because it is designed for 4,000 r.p.m. Standard motor is mounted by flange.

Fig. 5—Fuel booster pumps driven by motors of "explosion proof" construction for safety.

ing explosion-proof construction.

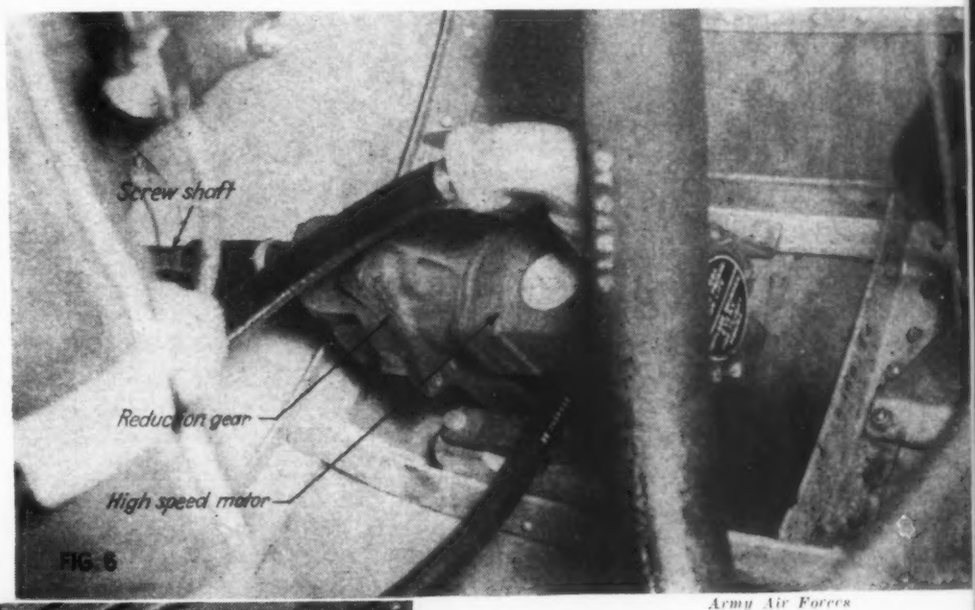
This design need not meet the Underwriters Laboratory standards because an aviation motor is usually exposed to only gasoline as an explosive. Standard practice of the Army Air Forces requires the motor to demonstrate that its operation will not cause an explosion, and that it will not propagate flame from an internal explosion to the exterior atmosphere thereby causing an explosion. An interesting possibility in these motor pump units has come with the use of 400 cycle motors. A three phase induction motor is the simplest possible electric motor design. A four pole 400 cycle motor will rotate at approximately 11,000 r.p.m. Experimental work with gear type pumps operating at this continuous speed shows great promise and reduction in space and weight while retaining respectable efficiency.

The third application for motors is often described as an actuator. Too often this motorized device has been designed as a linear actuator since it must compete with hydraulic designs. The problem is to move a force through a distance ranging from one to nearly 50 in. depending upon the application. The simplest design for such a problem is the hydraulic cylinder and piston. This is not the simplest design for an electric unit. It would be far simpler to use a rotary power output instead of a linear unit. The rotary design would avoid the need for a screw shaft with its fragility, exposure to dust and corrosion, and inefficiency. Much has been done to develop a ball bearing nut with a screw shaft that will provide a very high efficiency. (See "Design of Groove-Form Screws With Ball-Bearing Nuts," Product Engineering, June, 1945, page 471). Most other types of screw shafts will usually have efficiency of 20 to 50 percent.

Actuators for operation of landing gear and flaps will range from 1/10 to 7 hp. in rating, depending on the airplane design. These electric actuators are usually slower than the equivalent hydraulic design. This characteristic has been used as a condemning criticism of electric design for landing gear retraction and as an advantage for flap operation. Development of a suitable variable-ratio coupling will allow the electric actuator to deliver full power at all times just as the hydraulic design does and considerably reduce the retraction time.

Actuators for intermediate power requirements ranging from 1/20 to 1/4 hp. are used to operate such parts as cowl flaps, Fig. 6, and shutters for regulating devices. They relieve the pilot of constant surveillance of operating conditions around each engine.

Very low power actuators are used in landing lights and for remote control of trim tabs. The electric drive provides more flexibility in the aircraft installation and this is appreciated by the aircraft designer. The major problems in actuators is designing for low temperature operation and protection from dust, dirt and other contamination. Designing for efficiency is secondary in low power designs, because most applications are intermittent duty. In high power designs efficiency becomes important, because the current consumption may exceed the power capacity of the electrical system.



Army Air Forces

Fig. 6—Cowl flap actuator. High-speed motor and reduction gearing drives screw shaft (left) that transmits linear motion to move cowl flaps.

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A fourth application for electric motors is for instruments. Gyroscopes were formerly operated as a turbine by pneumatic power. This was not completely satisfactory since the flow of air introduced dirt and corrosive influences. Also, the in-

crease in operating altitude made it more and more difficult to maintain the desired suction or operating pressure and the lower friction or drag in the upper air permitted the gyroscope to reach excessive speeds. Use of electric power, whether d.c. or a.c. has permitted the complete sealing of gyroscopes. In the d.c. designs, there is still some contamination because of carbon dust from the commutator and brushes. This is avoided by the use of an induction motor, so there is an increasing trend towards a.c. power for gyroscopes.

Another type of instrument motor gives remote indication. Self synchronous motors are used in pairs. One motor is located at the device that is having its position indicated. It is connected by three to five leads to a second motor at the pilot's instrument panel. The second motor drives only a pointer and gives a relatively accurate indication of the position of the first motor.

A new trend in indicators is towards a null seeking pointer that is driven by an electric motor. This design is being used where the device that is having its position indicated cannot deliver sufficient torque to operate even a self-synchronous motor. The position is detected by a magnetic, or even a visual light, coupling. The null motor drives the indicator to a position that corresponds to that of the device. This places all of the power at the indicator and makes that power independent of the signaling device, thus improving accuracy.

The fifth application of electric motors is the servo device. This always requires an auxiliary coupling of infinitely variable-ratio to provide speed variation and reversal of output power. There are four generally used solutions. The first is a continuously running motor operating a pair of clutches and brakes to a planetary and differential gear system that drives the output shaft. Power is delivered in the required direction by energizing one clutch. The other gear system is held in a braked position. Output power is delivered through a differential in the required direction. For low power, some variation in speed is provided by slippage of the clutch.

A second solution is electro-hydraulic. In this drive a continuously operating uni-directional electric motor drives a hydraulic pump and the output of the pump is controlled to deliver servo power. This solution has all the characteristics of a normal hydraulic system, but substitutes electric wiring for hydraulic piping, as shown in Fig. 7. A third solution is an electro-mechanical drive. This method shows considerable promise and the results of service tests will determine its final usage.

The fourth solution is electrical. This requires a motor generator set in which the output voltage of the generator can be varied. This is basically the Ward-Leonard system, but the most widely used design in aircraft is the Amplidyne, Fig. 8. In this design the signal excitation controls power through short-circuited brushes across the armature. This in turn sets up cross field excitation in the generator. The voltage and power delivered by the generator is proportional to this cross field excitation. This gives a very large amplification combined with extreme sensitivity. It has been very successfully used for gun turret motors, which represent a particularly severe servo problem. It has also been used by the Sperry Gyroscope Company in a recently designed automatic pilot.

Electric motors have several definite advantages for use in aircraft. They are relatively low in cost because of their wide usage in commercial applications. Electric motors are reliable, particularly when manufactured to meet high standards and when internal protection is incorporated so that failure of the driven apparatus will not burn out the motor. Their relatively high weight is more than compensated for by the low competitive weight of electric wiring, especially in the higher voltage systems.

Because of the expanding potential uses of motors in airplanes, electrical designers should continue to pare weights and shrink sizes. Primarily as a result of painstaking design in this direction will electric motors find their widest usefulness in helping advance the performance of aircraft.

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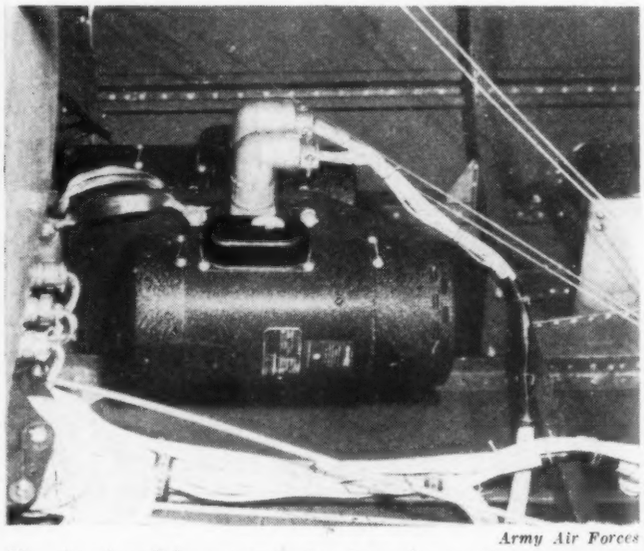
Fig. 7—Electro-hydraulic servo unit used by the Sperry Gyroscope Company. Electric motor operates continuously in one direction; hydraulic units are in lower case.



Army Air Forces

Fig. 8—Amplidyne generator is a d.c. motor generator set. Output of the generator is variable over wide limits of voltage. Unit gives large amplification with sensitivity.

NEW DIMENSION STANDARDS FOR FRACTIONAL HORSEPOWER MOTORS

Three NEMA fractional hp. motor frames for rigid and resilient base motors. Largest is interchangeable with standard 203 frame for integral hp. motors.

REALIZING the savings to be gained by machinery manufacturers, motor manufacturers and users, NEMA initiated a study of dimension standards in 1944 for fractional hp. motors that have now been adopted. According to J. L. McKinley, Wagner Electric Corporation, the new dimension standards provide for three motor frame sizes with dimensions as shown in Fig. 1. At the present time, no horsepower and speed ratings will be assigned to these frame sizes.

The dimensions apply to both rigid and resilient, or cushion base, motors in sizes 1/20 through 3/4 hp., 1,800 r.p.m. (1 hp., 3,600 r.p.m.). The *H* dimension of 13/32 in. slot and *BA* dimension of 3⅛ in. in the largest frame has been established for the purpose of matching the integral hp., 203 frame (1 hp., 1,800 r.p.m.). This provides for interchangeability on belt driven machines, using both fractional and integral hp. motors.

Each motor manufacturer now has a separate and distinct system of frame designations. Some manufacturers employ numbers, some letters, and others a combination of both to designate the various motor frame sizes. There are very few instances of similarity in the numerous systems. Consequently, purchasers and users of fractional hp. motors have found them confusing.

To make the new dimension standards more useful and effective, a standard system of numbering frames is proposed. This proposed system is modeled after the integral hp. system that uses frame sizes 203 through 505. The system for numbering integral hp. motors has been used successfully for approximately 16 years.

In the proposed system for numbering the frames, the frame number will be 16 times the shaft height, or *D* dimension. In the table accompanying Fig. 1, the three frames are 42, 56 and 66, and the *BA*, *E*, *F* and *H* dimensions will be constant for any given *D* dimension or frame size. Suffix letters will be used to indicate the same features as in the integral system. Therefore, the same frame numbers with proper suffix letters, when assigned, would be used for vertical and flange motors as are designated for the horizontal motors of corresponding sizes. Individual manufacturers may use any letter preceding the frame number, but such a letter would have no reference to standardized dimensions. For example, a number 66 frame might be designated as "66" by one manufacturer and as "A66" by another manufacturer, but as shown in Fig. 1, the *D*, *BA*, *E*, *F* and *H* dimensions of both frames will be identical.

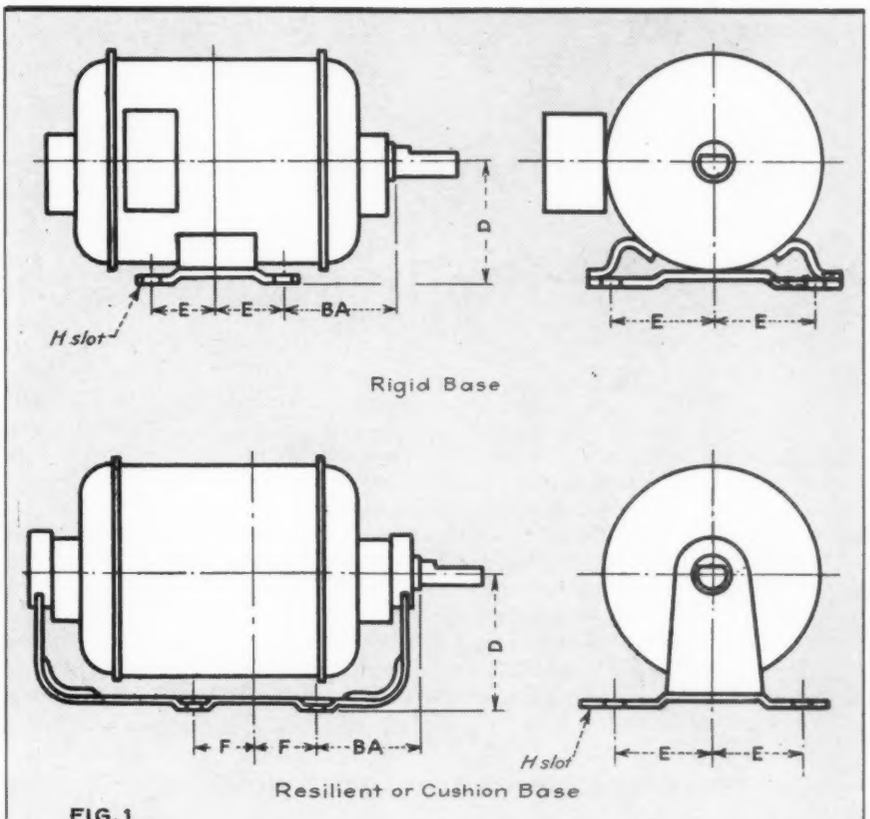


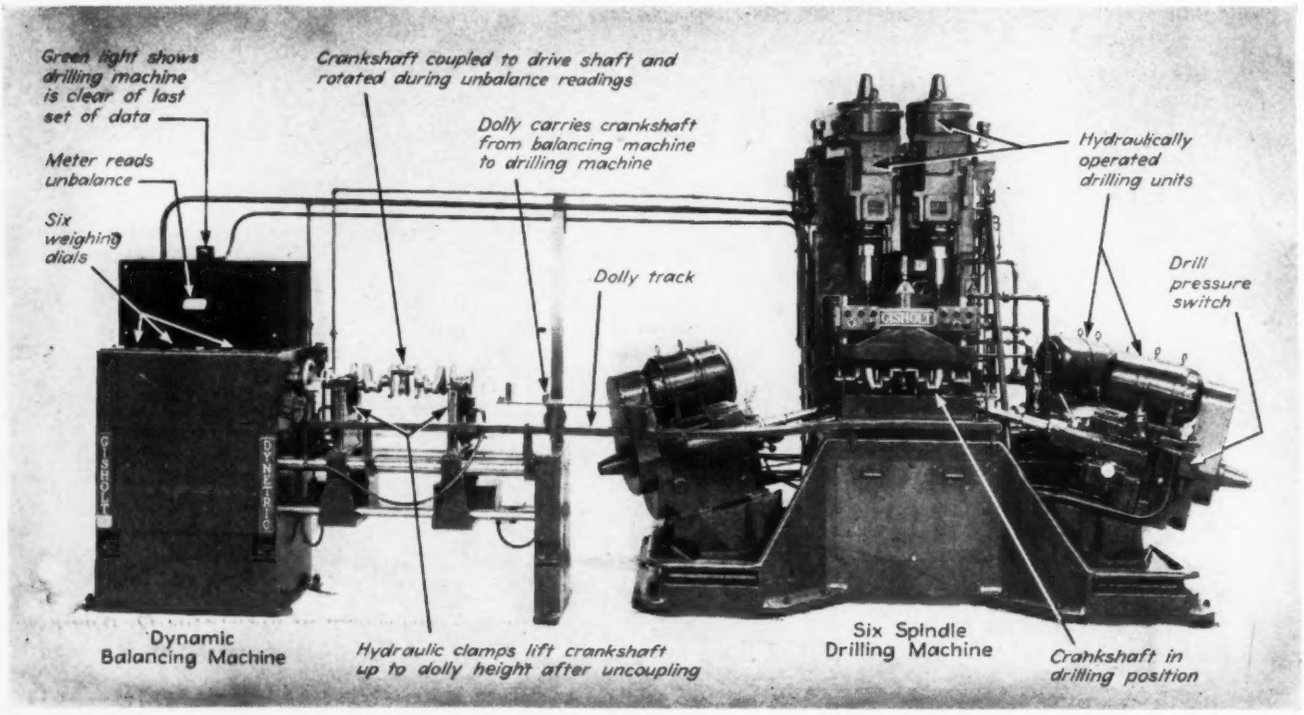
FIG. 1

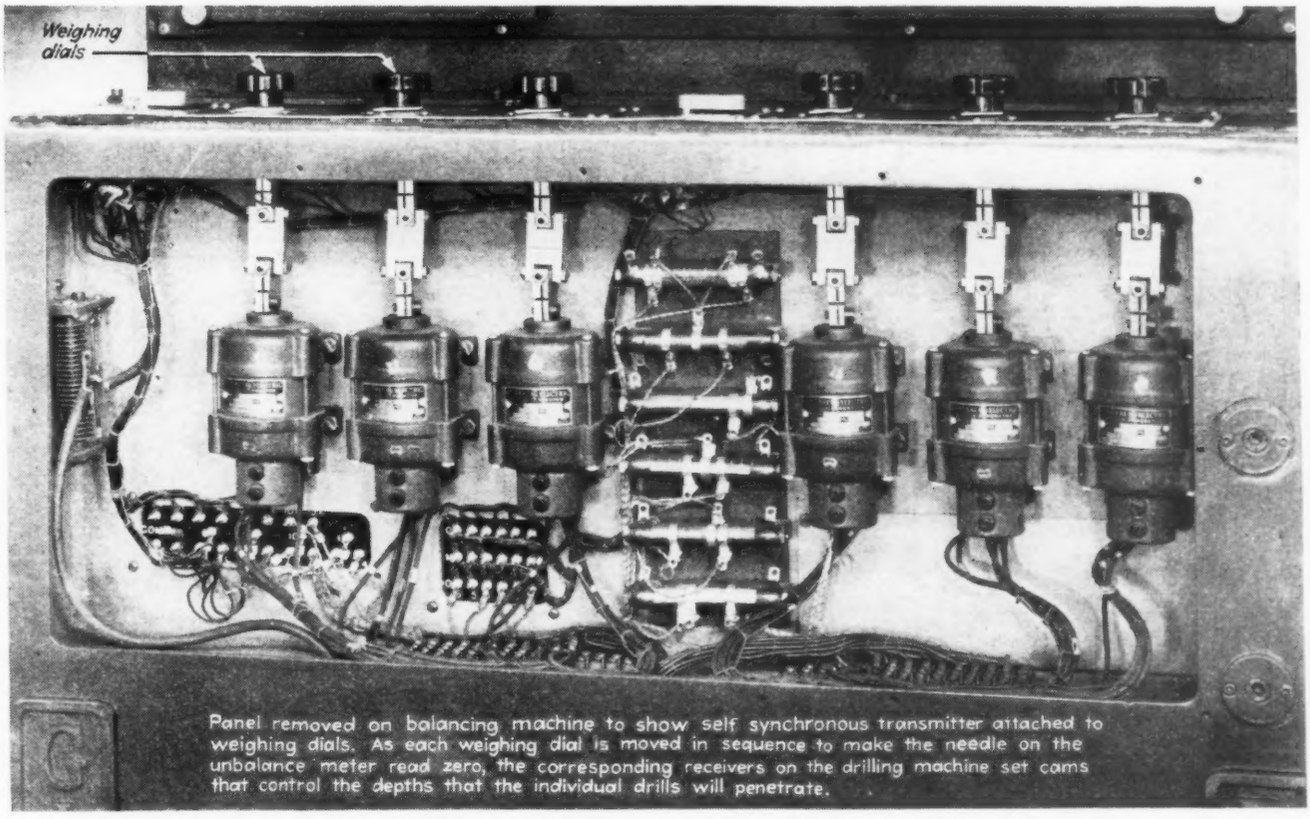
Proposed Frame No.	Dimension, In.				
	D	E	F	BA	H
42	2⅝	1¾	27/36	2	9/32 slot
56	3½	2 7/16	1½	2¾	11/32 slot
66	4⅛	2 15/16	2½	3⅛	13/32 slot

PRODUCT DESIGNS

Self-Synchronous Transmitters Electrically Couple Machine Tools

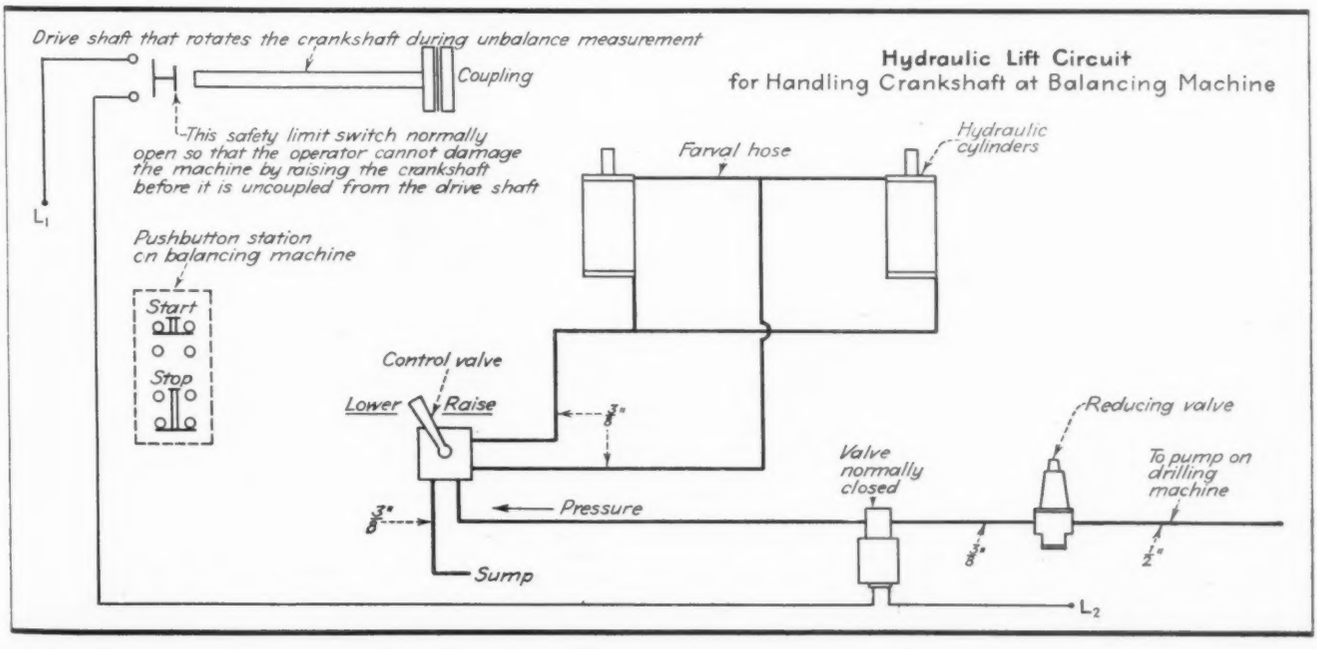
DYNAMIC balancing of a rotating part requires two elements—measuring and correcting the unbalance. Previously the operation was done by determining unbalance, then drilling out the required amount of metal on a separate machine by use of charts or trial and error methods. Results had to be checked frequently for accuracy. The Two-Element Dynamic Balancing Machine, developed by the Gisholt Machine Company, Madison, Wis., is semi-automatic equipment that measures and corrects dynamic balance of automotive crankshafts with speed and accuracy, using unskilled labor. Basically, it is a balancing machine that presets drilling units. An electric balancing machine is set up to indicate the amount of metal that must be removed. Because of the shape of crankshafts, metal must be removed from six specific points. Through self-synchronous transmitters and receivers the unbalance results are set on a six-spindle drilling machine that automatically drills the individual required corrections when the crankshaft is clamped in place. Overall average accuracy is 0.2 oz.-in. Balancing cycle time is 45 sec.; drilling cycle time including unloading is 60 seconds.


Green light shows drilling machine is clear of last set of data
Crankshaft coupled to drive shaft and rotated during unbalance readings
Dolly carries crankshaft from balancing machine to drilling machine
Hydraulically operated drilling units
Meter reads unbalance
Six weighing dials
Dolly track
Drill pressure switch
GISHOLT
DYNETRIC
Dynamic Balancing Machine
Hydraulic clamps lift crankshaft up to dolly height after uncoupling
Six Spindle Drilling Machine
Crankshaft in drilling position

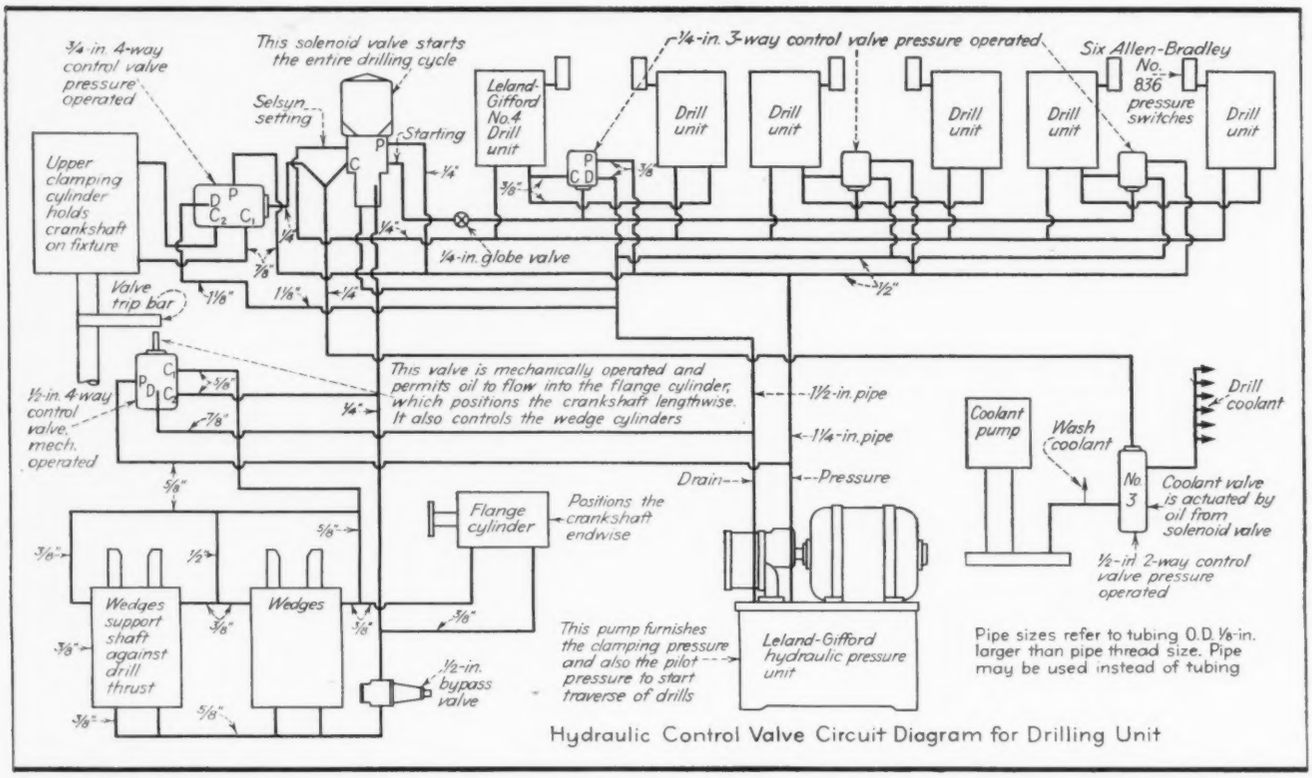


Panel removed on balancing machine to show self synchronous transmitter attached to weighing dials. As each weighing dial is moved in sequence to make the needle on the unbalance meter read zero, the corresponding receivers on the drilling machine set cams that control the depths that the individual drills will penetrate.

With the crankshaft rotating at 300 r.p.m., six weighing dials are turned in sequence to cause the meter on the balancing machine to read zero. Self-synchronous transmitters attached to each weighing dial set receivers for the corresponding self-contained hydraulically-fed drilling unit. After balancing, the crankshaft is hydraulically raised so that the operator can slide it onto a dolly. He gives the dolly a slight shove to roll it along a track to the drilling machine. Unbalance, measured in oz.-in., weight times radius, is corrected by drilling metal from six points. These points must be located in crankpin and counterweights because of lack of symmetry in the crankshaft. Radius of correction is established by these fixed drilling locations. Thus motion of the self-synchronous transmitter-receiver is a measure of the weight to be removed. The receiver carries a cam that converts the oz.-in. unbalance reading into inches of depth of hole to be drilled in the shaft by that particular drill unit.



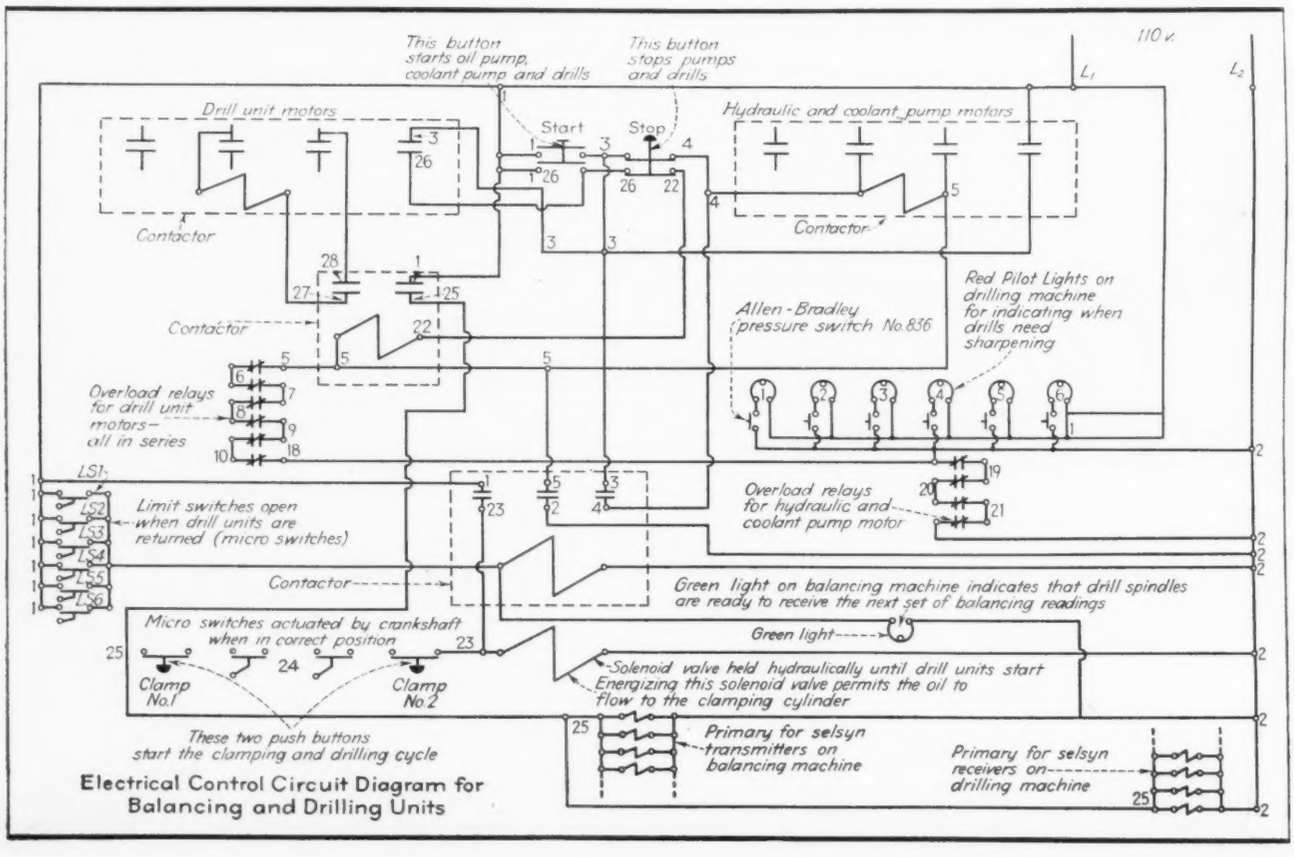
Self-Synchronous Transmitters (continued)


¾ in. 4-way control valve pressure operated
This solenoid valve starts the entire drilling cycle
¼-in. 3-way control valve pressure operated
Six Allen-Bradley No. 836 pressure switches
Selsyn setting
Starting
Leland-Gifford No.4 Drill unit
Drill unit
Upper clamping cylinder holds crankshaft on fixture
¼-in. globe valve
Valve trip bar
½-in. 4-way control valve, mech. operated
This valve is mechanically operated and permits oil to flow into the flange cylinder, which positions the crankshaft lengthwise. It also controls the wedge cylinders
1½-in. pipe
1¼-in. pipe
Drain
Pressure
Flange cylinder
Positions the crankshaft endwise
Wedges support shaft against drill thrust
Wedges
½-in. bypass valve
This pump furnishes the clamping pressure and also the pilot pressure to start traverse of drills
Leland-Gifford hydraulic pressure unit
Coolant pump
Wash coolant
Drill coolant
No. 3
Coolant valve is actuated by oil from solenoid valve
½-in 2-way control valve pressure operated
Pipe sizes refer to tubing O.D. ⅛-in. larger than pipe thread size. Pipe may be used instead of tubing

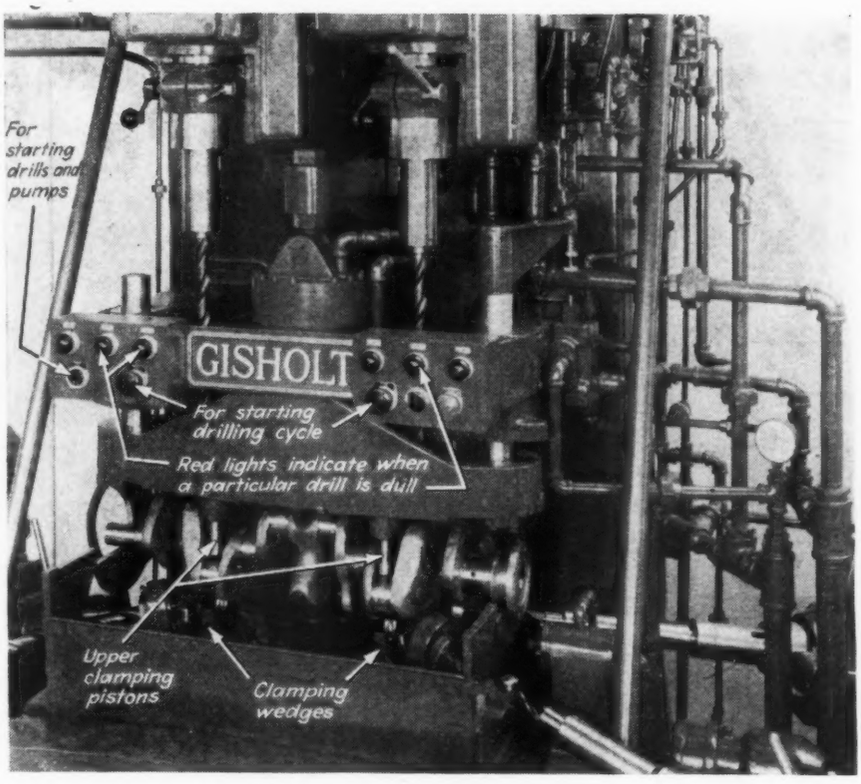
Hydraulic Control Valve Circuit Diagram for Drilling Unit

The drilling cycle consists of:

1. Hydraulically locating crankshaft in proper endwise position.
2. Clamping the crankshaft in the fixture.
3. Hydraulically bringing up wedges to support the crankshaft against distortion from the drill thrust.
4. Starting drill traverse and initiating coolant flow.
5. Causing each drill to drop into feed about ⅛ in. from the surface.
6. Initiating depth measurement for each drill separately as contact is made. This is done by mounting the hydraulic plunger that contacts the receiver cam so that the plunger is not clamped to the quill until the quill meets resistance.
7. Back traversing each drill separately when that drill has removed its prescribed amount of metal.
8. Unclamping the crankshaft and returning it to a position convenient for the operator.

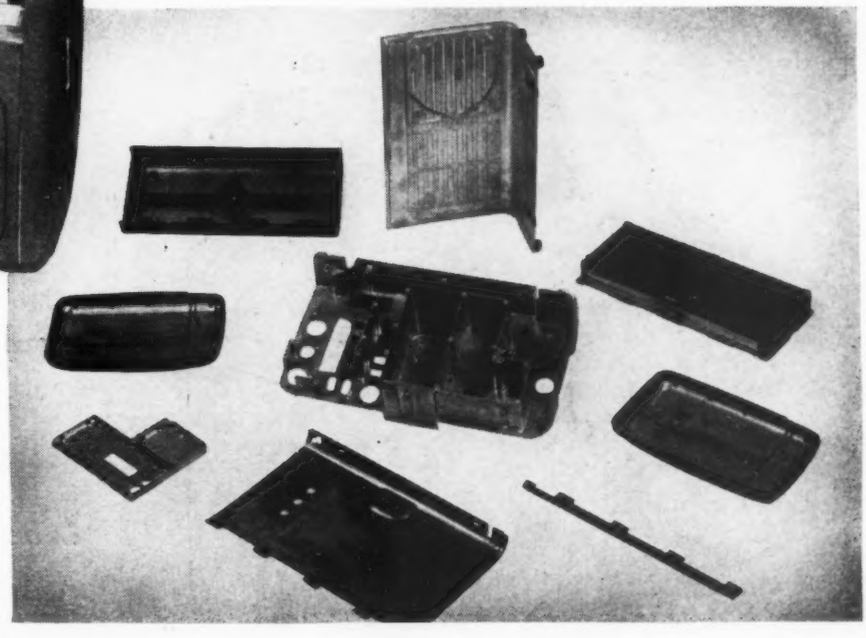

This button starts oil pump, coolant pump and drills
This button stops pumps and drills
110 v.
Drill unit motors
Start
Stop
Hydraulic and coolant pump motors
Contactor
Red Pilot Lights on drilling machine for indicating when drills need sharpening
Allen-Bradley pressure switch No. 836
Overload relays for drill unit motors—all in series
Overload relays for hydraulic and coolant pump motor
Limit switches open when drill units are returned (micro switches)
Green light on balancing machine indicates that drill spindles are ready to receive the next set of balancing readings
Green light
Micro switches actuated by crankshaft when in correct position
Clamp No. 1
Clamp No. 2
Solenoid valve held hydraulically until drill units start
Energizing this solenoid valve permits the oil to flow to the clamping cylinder
These two push buttons start the clamping and drilling cycle
Primary for selsyn transmitters on balancing machine
Primary for selsyn receivers on drilling machine

Electrical Control Circuit Diagram for Balancing and Drilling Units

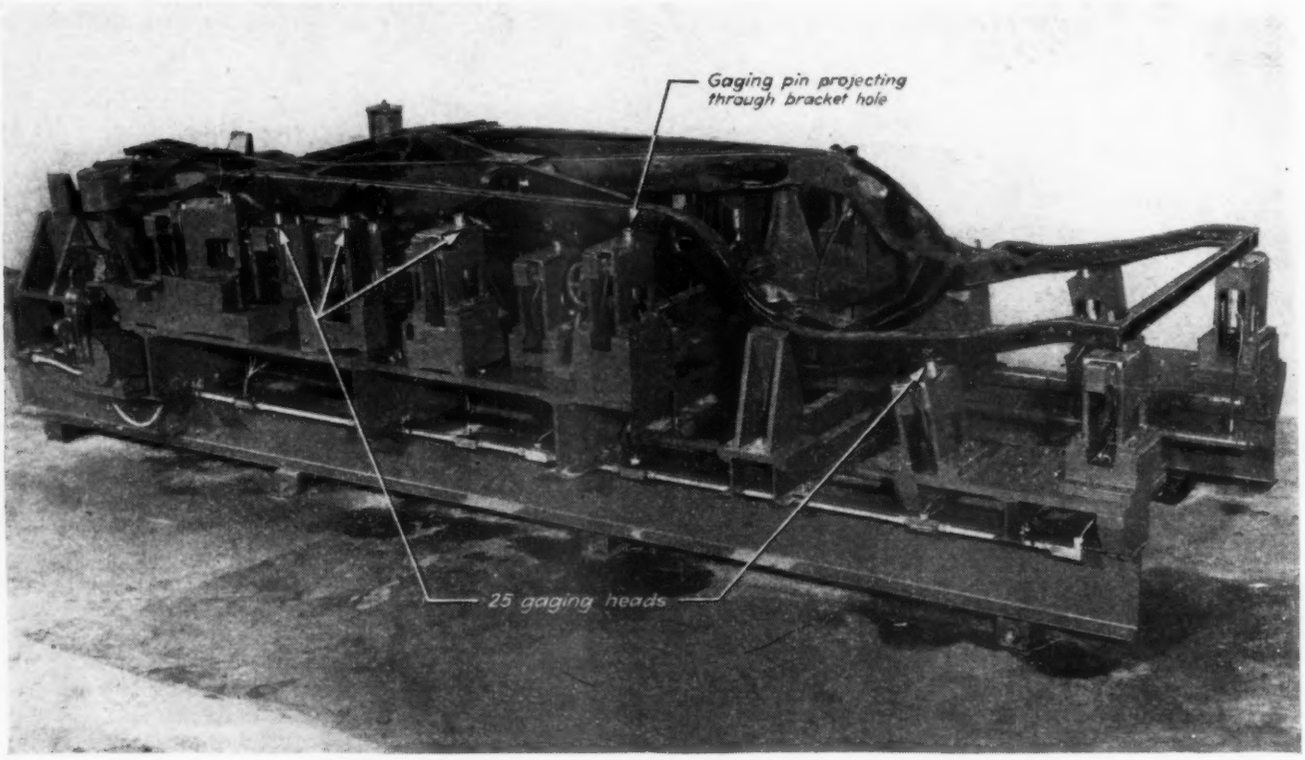

For starting drills and pumps
GISHOLT
For starting drilling cycle
Red lights indicate when a particular drill is dull
Upper clamping pistons
Clamping wedges

Dolly Carries the crankshaft in the proper angular position for correction drilling. Drill operator shoves the crankshaft onto a fixture. For safety, a start button must be pushed with each hand. The crankshaft is hydraulically located endwise, clamped and wedged against drill thrust. Drills advance, drop into feed about $\frac{1}{8}$ in. from the surface and initiate depth measurement separately upon contact. When drill traverse is initiated a depth gage contacts the cam on the receiver, so setting the depth measurement for that hole. Upon completion, the drills automatically back traverse, the piece is unclamped and thrown forward for convenient handling. Three seconds after the drilling cycle starts, a green light on the balancing machine glows to indicate to the operator that the spindles are set for the work in the driller and balancing on a new piece may commence. Should any drill become dull, the increased hydraulic pressure required will actuate a numbered red light. The light stays on until that drill is changed and the pressure switch manually reset.

Aluminum Die Castings Inclose Self-Charging Radio

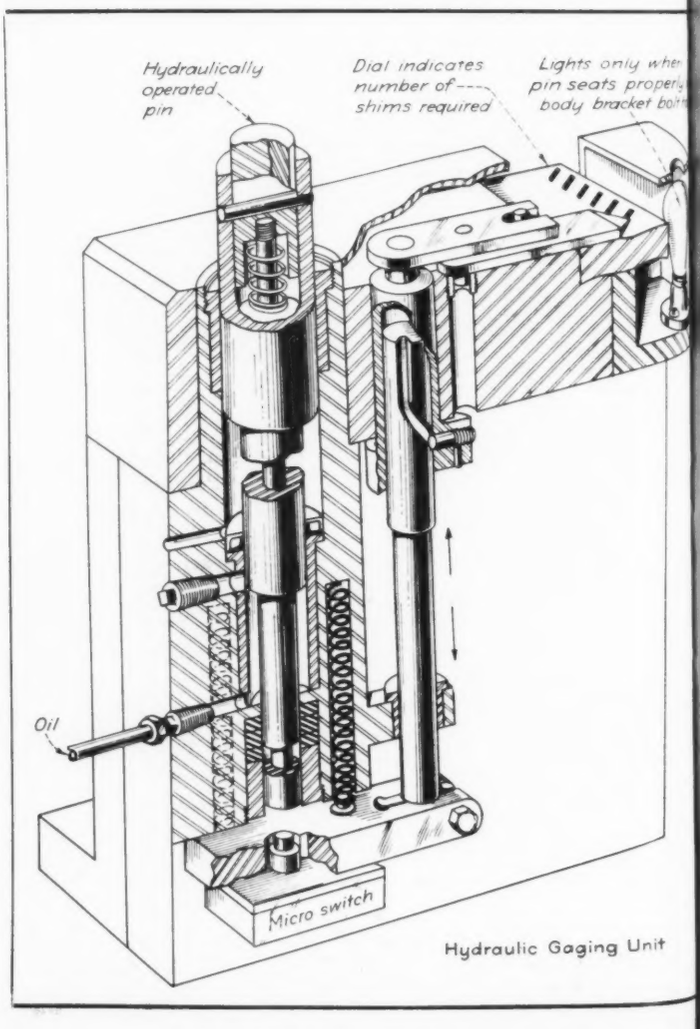


Aluminum die castings are used to make a strong, light, portable radio cabinet. The portable radio, which can be plugged into a.c. house current for recharging, has been developed by the General Electric Company, Schenectady, N. Y. The 2-volt storage battery will operate the set 20 hours on a single charge. The set weighs 20 lb. and can be recharged while playing.

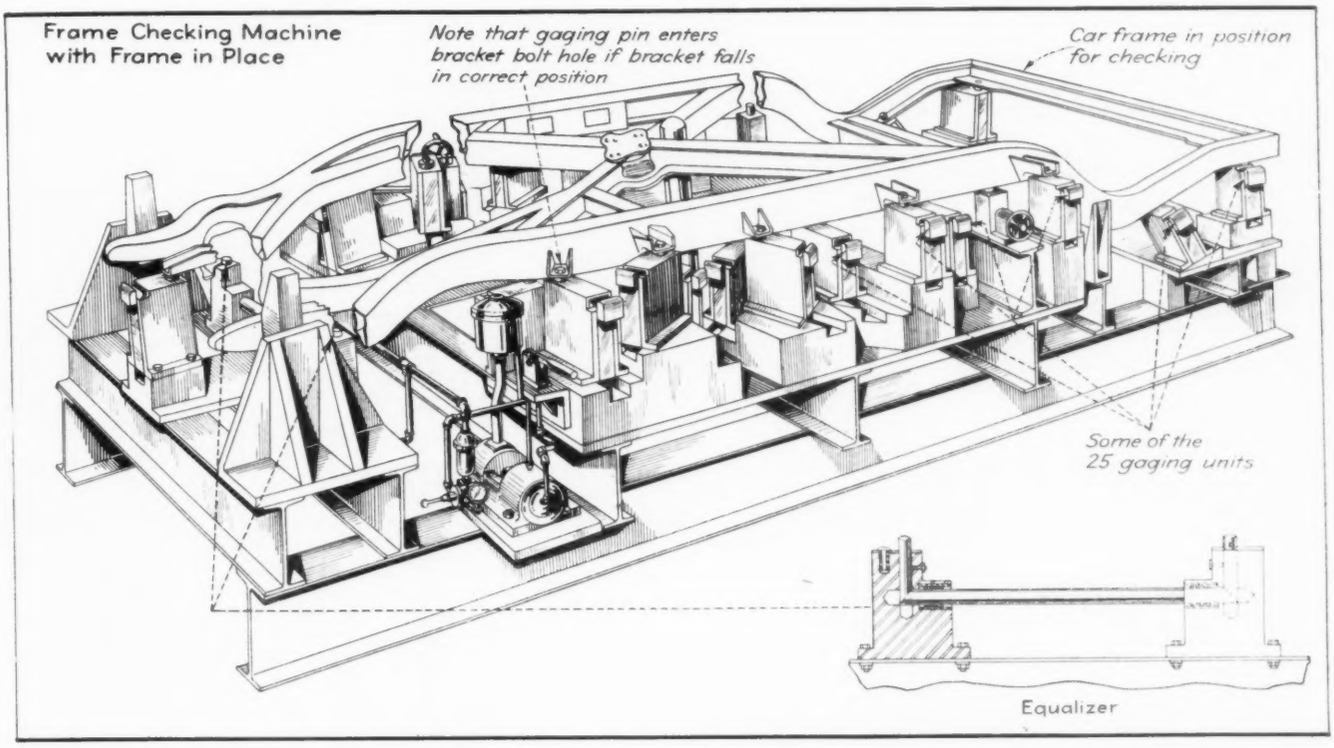


Hydraulic Gaging Units Check Frame Alignment

BOLT HOLES in chassis frames are checked for dimensional limits in the fixture developed by Buick Motor Division of General Motors Corporation. This fixture also checks height variations in brackets to determine how many $\frac{1}{16}$-in. shims are required between bracket and body. Since the frame manufacturer must have reasonable tolerances in bracket height, different thickness of shims are usually required between body and brackets to obtain a uniform mounting plane. Previously, assembly workers chose the number of shims needed, applying them before bolts were tightened. Assembly delays, caused by distorted frames, are prevented by verifying frame alignment on this gaging fixture.

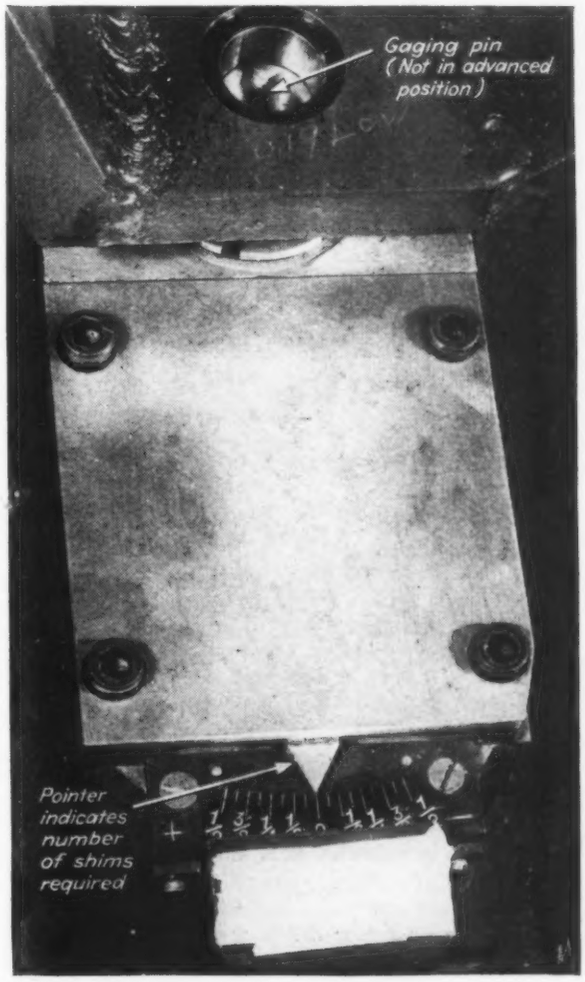


Hydraulic Gaging Unit


Frame Checking Machine with Frame in Place
Note that gaging pin enters bracket bolt hole if bracket falls in correct position
Car frame in position for checking
Some of the 25 gaging units
Equalizer

Twenty-five gaging units are mounted on fixture base made from structural shapes. Each gaging head has an hydraulic ram comprising a pin and sleeve that are advanced after the frame has been set bottom up on the fixture. The frame is positioned and locked by fore and aft dowel pins. It rests on an equalizer that is a horizontal bar with ends faced at a 45-deg. angle and two mating vertical pins. After locking the frame, hydraulic pressure is applied to the gaging units. Plungers in these units are thus caused to advance and each pin should enter a corresponding bracket hole. Pins are $\frac{7}{8}$ in dia., the same as body bolts, but holes for them are $1\frac{1}{8}$ in. dia. to allow clearance. A light and an indicating pointer are on each unit. If the pin enters the bolt hole, the light goes on and the inspectors know that the hole location is correct. If the pin does not enter, the bracket is aligned by hammer blows.

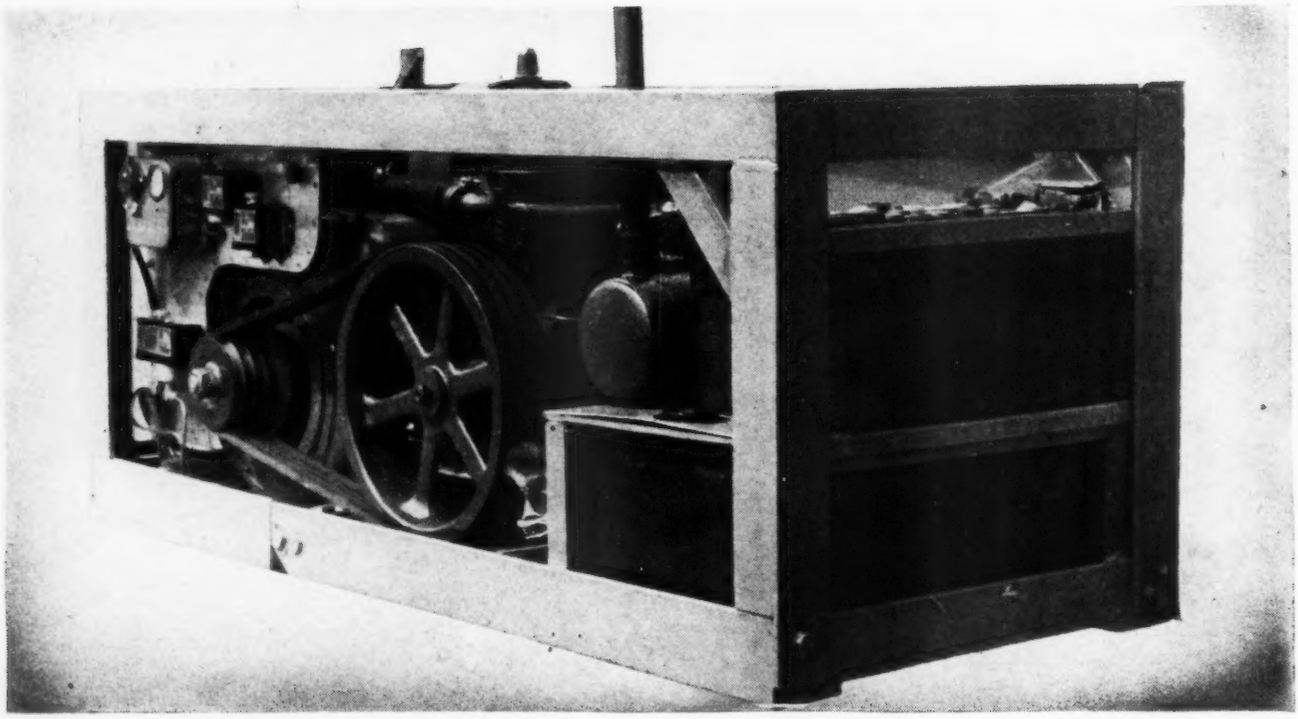
When all lights are on, the inspector reads the gage on each fixture. Pointers show how far the particular brackets are from correct height. The operator marks the bracket with a prick punch indentation mark for each shim of $\frac{1}{16}$-in. thickness required.



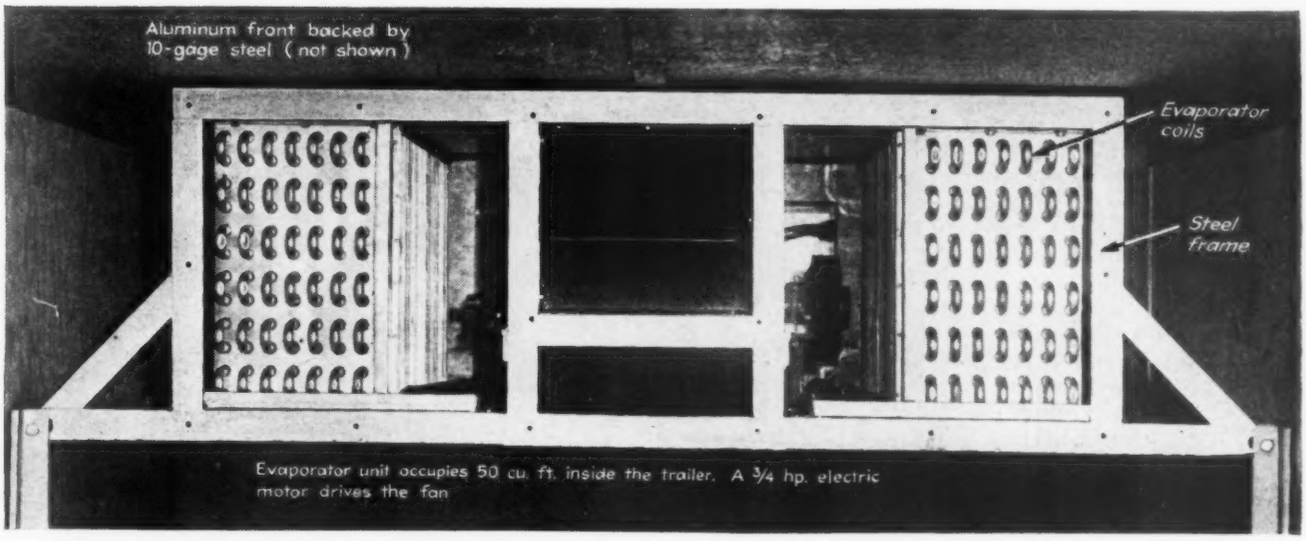
Hydraulic gaging unit pointer is actuated by lever at base of corresponding hydraulic cylinder. Lever is pivoted to a vertical bar carrying a sleeve with coarse-pitch thread or helical groove into which a fixed pin projects. As sleeve is moved axially, the pin causes the lever to turn a distance proportional to the motion. In turning, a lever attached to the pointer moves over a scale that indicates the deflection and number of shims needed on the particular bracket.

Hot Gas From Condenser Unit Defrosts Evaporator Coils

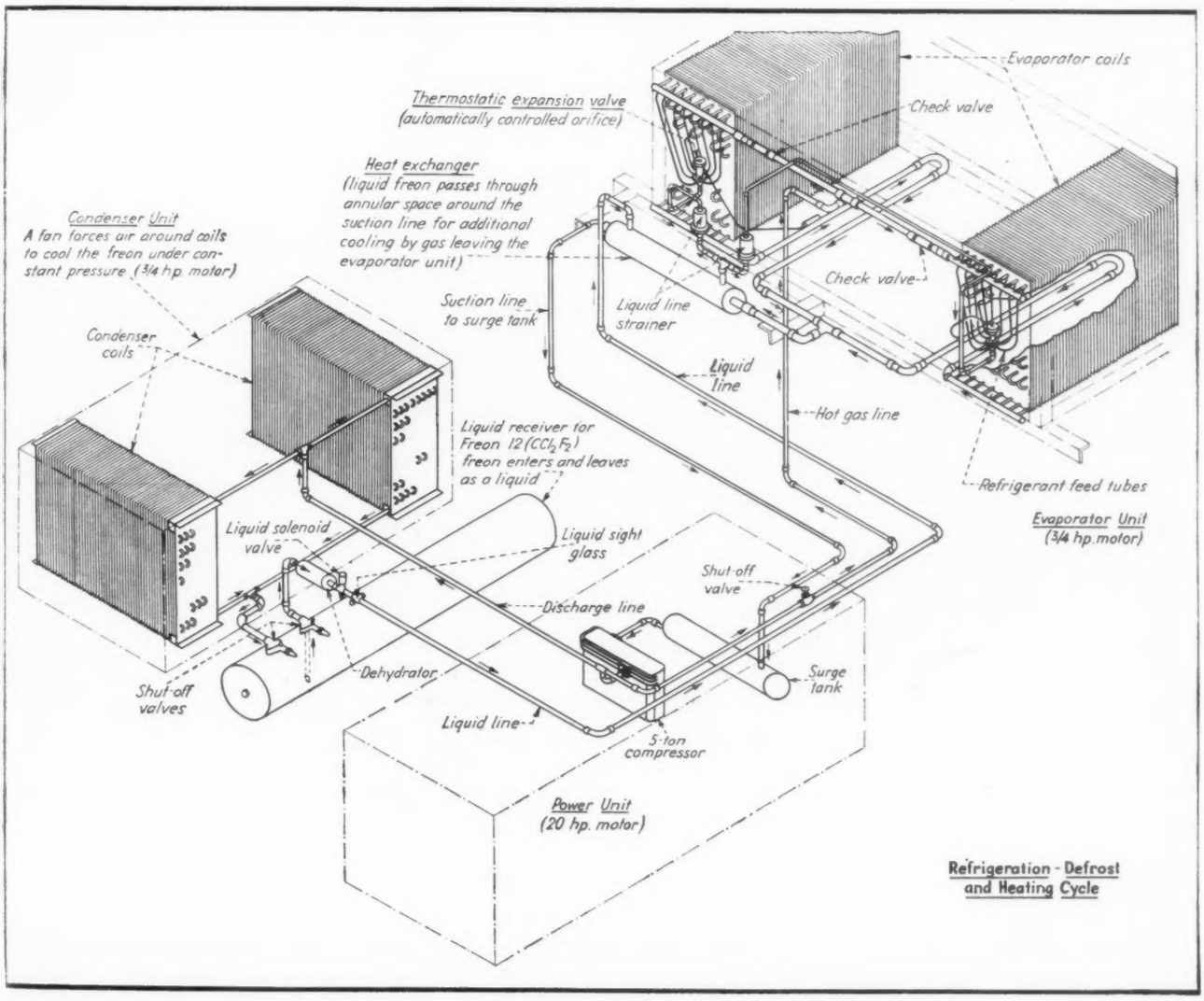
Evaporators in this truck refrigeration unit are cleared of ice in less than ten minutes by leading hot gas directly from the compressor unit to the evaporator coils. Thermostatic control of defrosting, combined with the usual refrigerating cycle, enables the unit to hold any interior temperature from 125 to —20 deg. F. regardless of exterior temperature changes. The 5-ton gasoline-powered automatically controlled refrigeration unit is built by the American Manufacturing Company, Montgomery, Ala. Power unit and compressor, sheathed in aluminum, are mounted beneath the main frame and the skirting of the trailer.



Power train consists of a 20 hp. gasoline engine, starter, generator, clutch, 5-ton compressor, surge tank, battery, gasoline tank and an electrically controlled thermostat. A ¾ hp. electric motor drives the fan that cools the 2-unit condenser. Condenser is mounted on side of trailer opposite power train. The thermostatic control starts the engine when trailer temperature varies 3 deg. from the selected setting. Once the load is cooled, the engine is said to operate about 40 percent of the time consuming 1 g.p.h. By releasing a latch the engine can be dropped for quick servicing.


Aluminum front backed by
10-gage steel (not shown)
Evaporator coils
Steel frame
Evaporator unit occupies 50 cu. ft. inside the trailer. A 3/4 hp. electric motor drives the fan

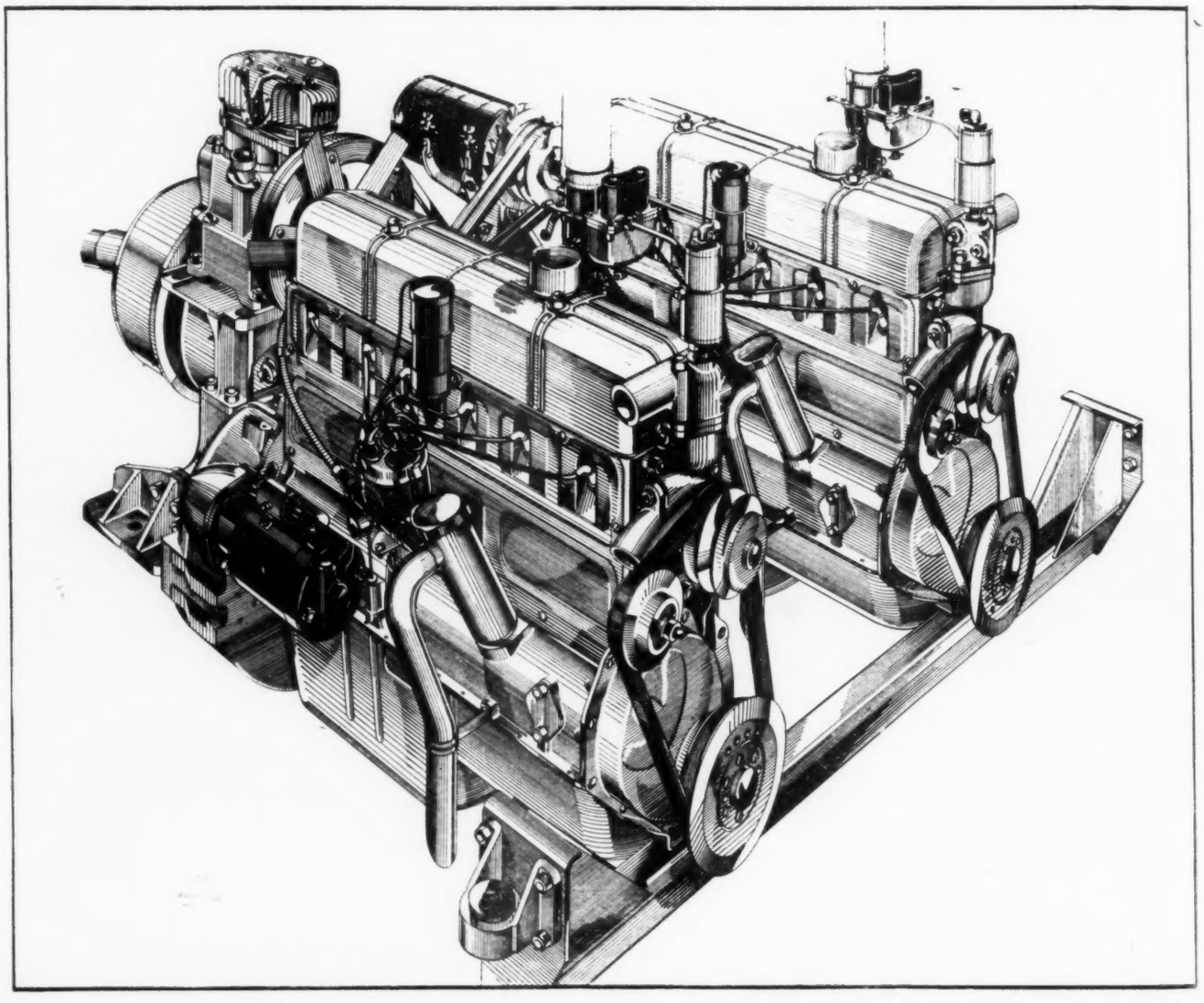
Defrosting is done through a line tapped into the compressor discharge line. A manually operated valve and two automatic check valves permit hot gas to travel into the compressor. After defrosting the coils, the gas goes to the surge tank where it is reheated and then returned to the compressor. During this cycle, the condenser and evaporator motors and the liquid solenoid valve are shut off so that defrosting action is maintained with minimum temperature rise. Economical defrosting, combined with efficient temperature control, adapts the unit to long distance haulage.

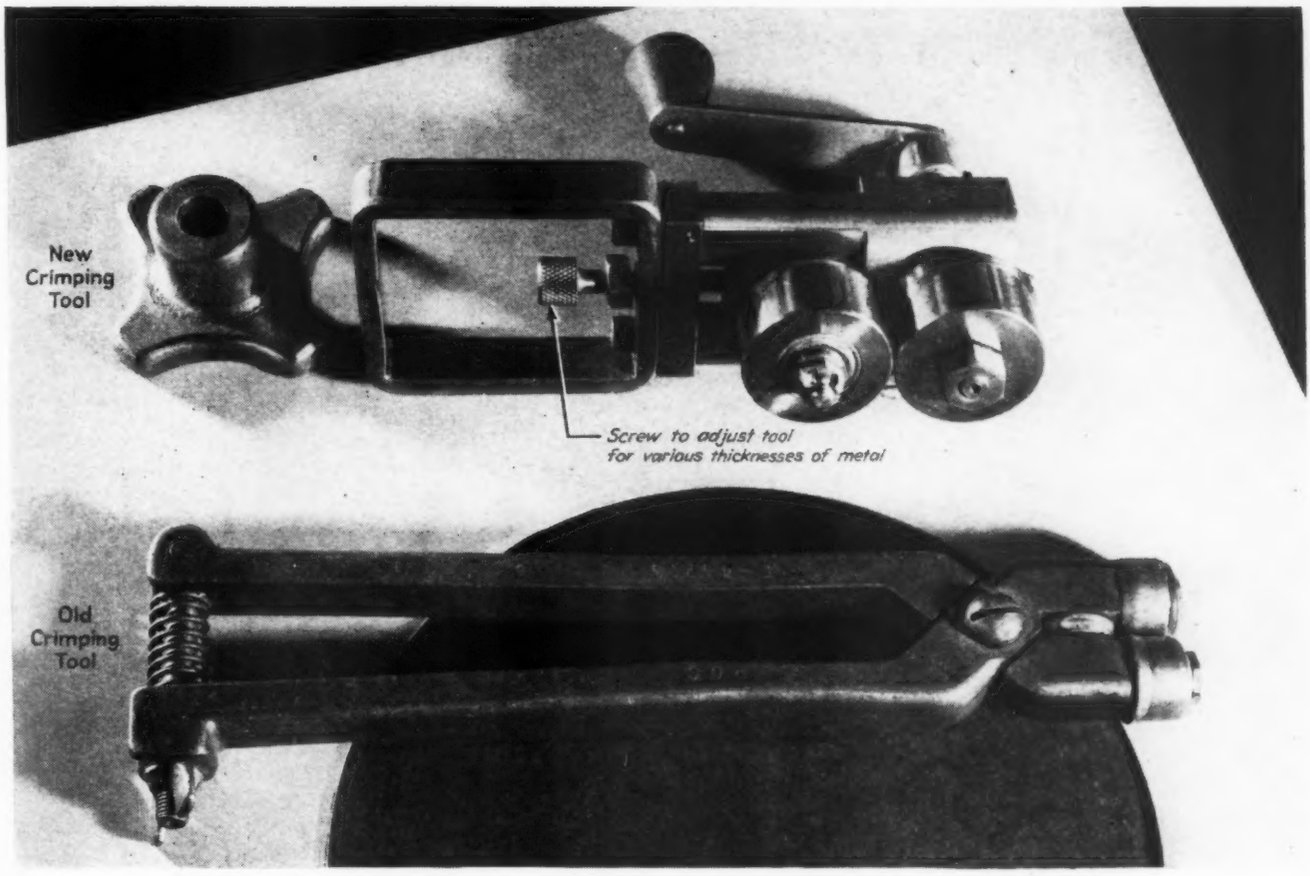

Evaporator coils
Thermostatic expansion valve (automatically controlled orifice)
Check valve
Heat exchanger (liquid freon passes through annular space around the suction line for additional cooling by gas leaving the evaporator unit)
Condenser Unit
A fan forces air around coils to cool the freon under constant pressure (3/4 hp. motor)
Check valve
Suction line to surge tank
Liquid line strainer
Condenser coils
Liquid line
Hot gas line
Liquid receiver for Freon 12 (CCl_2F_2) freon enters and leaves as a liquid
Refrigerant feed tubes
Evaporator Unit (3/4 hp. motor)
Liquid solenoid valve
Liquid sight glass
Shut-off valve
Discharge line
Dehydrator
Surge tank
Shut-off valves
Liquid line
5-ton compressor
Power Unit (20 hp. motor)
Refrigeration - Defrost and Heating Cycle

Twin Engine Power Plant Has Several Advantages

DUAL ENGINES, combining their output in a single transmission, power the 37-passenger Clipper bus built by the Flexible Company of Loudonville, Ohio. The bus can operate on one engine. Either engine can be used to start the other in an emergency. Total weight of the two engines is less than the weight of many single engines of the same horsepower. The bus has a summer cooling and winter heating system with individual heat controls at each pair of seats. The body is of corrosion resistant aluminum with airplane type construction. Curb weight, unloaded, is 15,500 pounds.

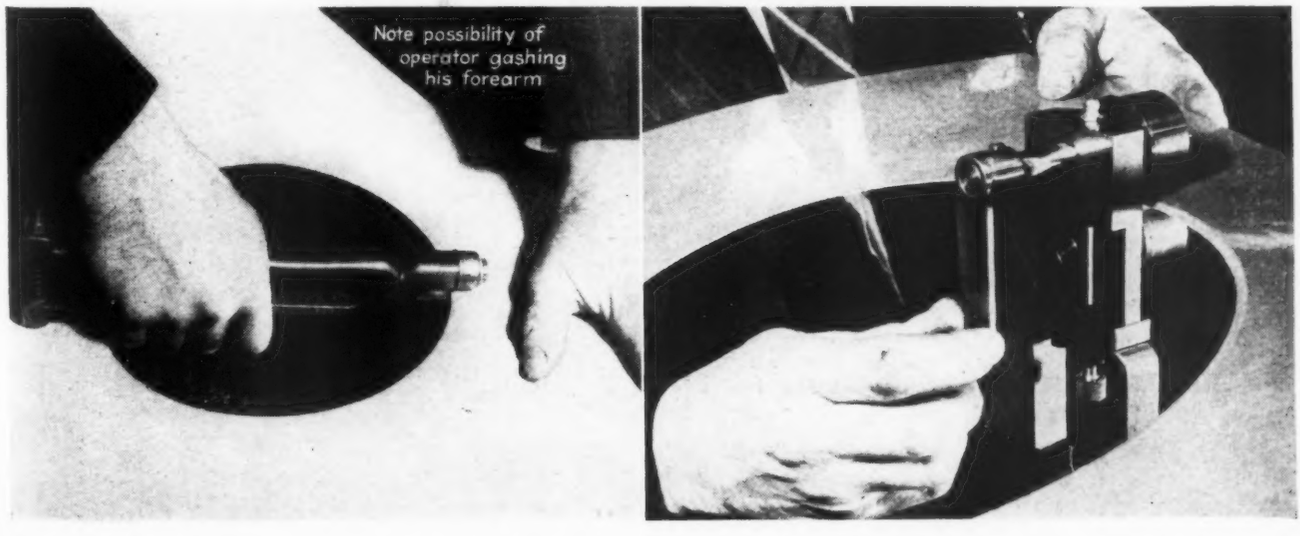
Two 93-horsepower Chevrolet truck engines are mounted side by side in the rear of the bus. Each engine has its own starter motor. By using a widely accepted small engine, initial and maintenance costs are kept low. Twelve cylinders are said to give a noticeably smoother power flow than single large engines.





Improved Crimping Tool

OPERATING in the manner of the familiar can opener, a crimping tool that will handle sheet metal up to 16-gage has been perfected by Frank Lucarelli, Tool Designer of the Glenn L. Martin Company, Baltimore. Two round dies, the mating elements of which prescribe the desired shape of the crimp, are held togther by spring tension. An adjustable screw adapts them for various thicknesses of metal. By turning the crank the metal sheet is pulled between the dies and crimped. The tool may be used at the bench or on the job. Former crimping tool resembled a pair of pliers; if this tool slipped the operator might gash his arm on the edge of metal sheet. The new design does not present this hazard in operation.

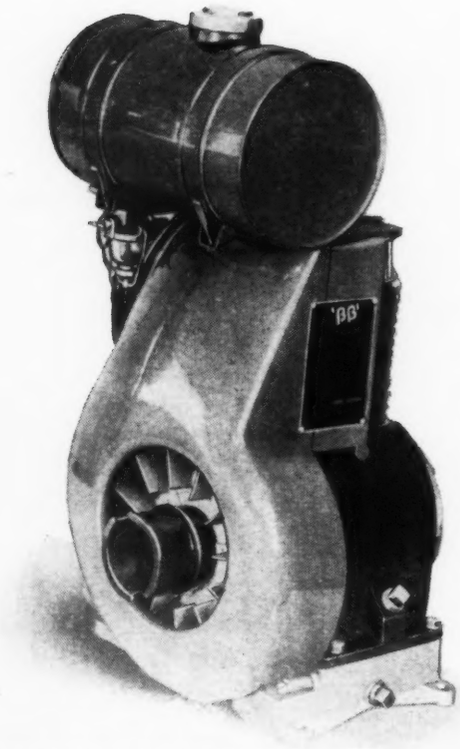


PRODUCT DESIGN *briefs*

Room Air Conditioner

This window sill model will condition the air in rooms up to 15 x 19 ft. The conditioner lowers humidity and temperature, cleans and circulates the air, and can remove stale inside air. Filter pads are readily changed by lifting the grill at the upper right-hand corner of the machine. It is operated by a one-half horsepower motor. While cooling, the conditioner can remove 60 cu. ft of stale air per min.; without cooling, it can change 240 cu. ft. of air per min. It will remove a quart of water hourly and is capable of removing 5,250 B.t.u. each hour when the outside temperature is 90 deg. dry bulb, 75 deg. wet bulb, and inside temperature is 80 deg. 50 percent relative humidity.

Manufacturer: York Corporation, York, Pa.



Manufacturer: Gladden Products Corp., Glendale, Calif.

Low Hp. Gasoline Engine

Occupying 2.9 cu. ft. with an overall height of 23 in. the power range of this 4-cycle, air-cooled engine is 2.5 to 4.3 hp. Head, piston, and connecting rod are of aluminum alloy. Dynamically-balanced crankshaft is forged of alloy steel, with journals hardened and ground. Crankcase-block casting is of Meehanite, cowling of pressed steel.

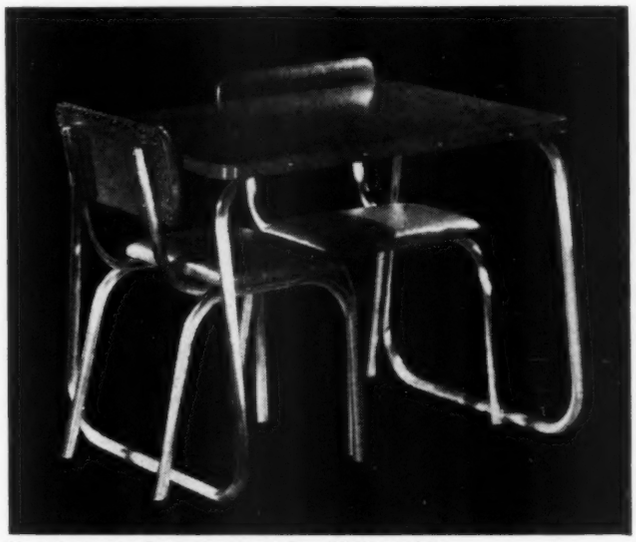
Fiberglas-Plastic in Compound Curve Shapes

Fiberglas-reinforced plastic aircraft parts illustrate adaptability of the material to fabrication of complex compound-curve parts. The small three-outlet duct on table, center, incorporates a flexible coupling outlet and the rigid duct in an integral molded unit. The cockpit heat control valves, two on the table, one resting on the small box, have metal bearing inserts. A two-piece engine cowling for the engine of a radio-controlled target plane is shown in foreground. The three large units are header ducts.

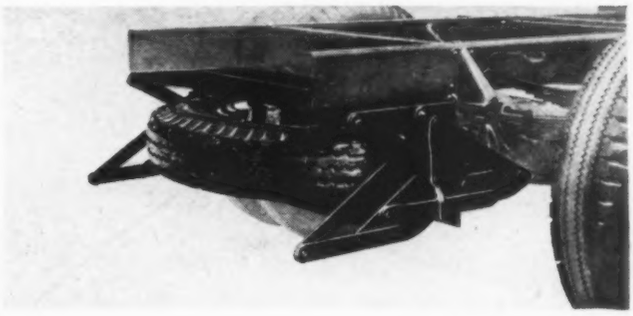
Manufacturer: Industrial Plastics Corp., Gardena, Calif.

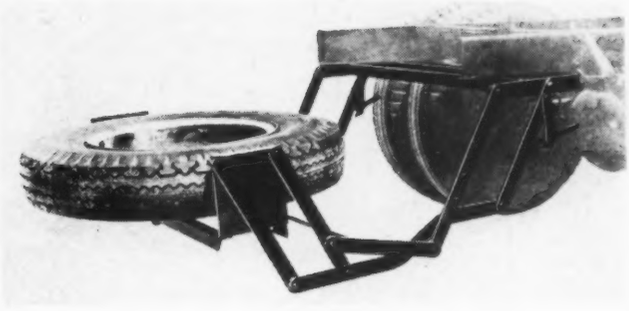
Magnesium Furniture

The frame work of this children's furniture is of $\frac{3}{4}$ in. extruded magnesium tubing. These chairs can support 250 lb., yet weigh but $2\frac{1}{2}$ lb. each. The table has an 18 x 24 in. hardwood top enameled to match the upholstery.



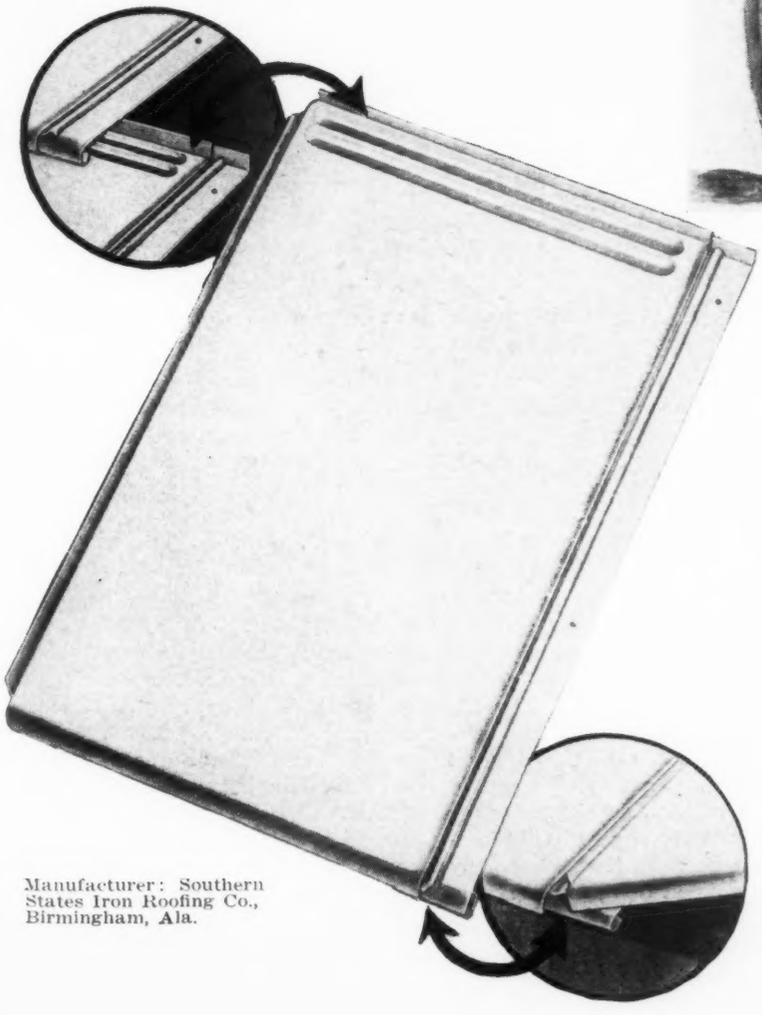
Manufacturer: Dow Chemical Co., Midland, Mich.





Tire Carrier

Heavy truck spare tires are easily handled by one man using this carrier. The linkage of the members allows the cradle with tire and wheel to be pulled out from the truck body to a position where the tire is clear. Tire is tilted upright while still attached to the carrier. Release of the holding clamp then frees the tire.



Manufacturer: Southern States Iron Roofing Co., Birmingham, Ala.

Interlocking Aluminum Shingles

Natural finish aluminum shingles of 0.019 in. sheet are said to keep a building about 15 deg. cooler than conventional roofs on a hot day because of their reflective capacity. The shingles interlock at the side lap. Painted shingles are produced by cleaning with an alkali, rinsing, then dipping in a phosphoric acid solution which slightly etches the surface and leaves a light phosphate film coating. Synthetic enamel is then sprayed on and baked.

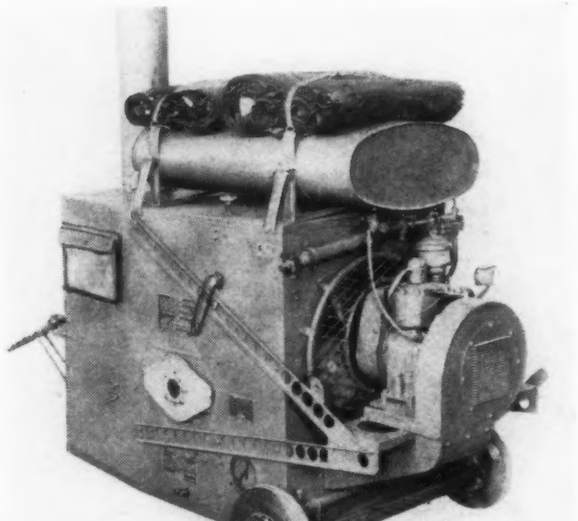
Manufacturer: Home Ola Corp., Chicago, Ill.

Sheet Metal Stairs

Pressed steel sections that combine tread and riser in one piece of formed metal are punched and slotted so that a full stairway can be assembled from the sections in 90 min. Standard unit is of 12 gage steel with a 36 in. width, a 9 in. tread, and a 7½ in. riser. The sections are bolted together through the slotted hole with the lip extending above the tread. This lock permits adjustment for height of rise to the extent of 1 in. per unit. Stairs are finished in standard gray and may be covered with rubber treads or carpeting.

Portable Heater

This gasoline burning general utility heater weighs 312 lb., can be transported from place to place by one man, and has heat output of 190,000 to 250,000 B.t.u. per hour. The heater consists of an enclosed, gravity fed combustion chamber and a finned, stainless steel heat exchanger. An axial fan powered by a small gasoline engine forces ventilating air across the outside of the heat exchanger. The heated air is discharged through collapsible ducts 12 in. d. waterproof, flame and heat resistant. They can be extended any desired length up to 24 feet.



Manufacturer: Herman Nelson Corp., Moline, Ill.

Direct temperature readings up to 1200 deg. C. were possible with the gallium thermometer used in Germany. The thermometer consisted of a thin quartz capillary rod inside a 60 cm. quartz envelope tube. The bottom of the capillary rod was broadened out and fused with the envelope to form a bulb. After the proper amount of gallium was put into the bulb, evidently under vacuum, the remaining space was filled with hydrogen at about 7 lb. per sq. in. and the capillary was sealed. A detailed report will be found in PB-25550 OTS. Write Department of Commerce, Washington, D. C.

Jet propulsion has been successfully used in a helicopter now undergoing tests at Wright Field, Ohio. The German helicopter operates by piping exhaust from a jet engine through the rotor blade terminals, and thus revolving them. A pusher propeller at the rear of the fuselage provides a slip-stream for directional control. A small motor powers the propeller. Fuel consumption for the jet unit is six times greater than that required in a standard helicopter, but the engine is used for such brief periods that this is not considered a serious disadvantage. The jet is not used for forward propulsion, but only in going up, down or hovering.

Aluminum-base metallic fibers have been introduced into the fashion world for clothing, shoes and upholstery fabrics. The new yarn, developed by the Dobeckmum Company in collaboration with the Eastman Kodak Company and the Aluminum Company of America, is an aluminum-base fiber sandwiched between two plies of plastic film. The special process and adhesives make the metal impervious to tarnish and lighter than ordinary metallic yarns. The yarn is made in gold, silver and copper colors. Iridescent hues are to be introduced shortly. The material has potentialities in the industrial field as well as for the food and packaging industries.

Solid nylon sheeting in bright colors is being manufactured in experimental lots by the E. I. du Pont de Nemours Company, Wilmington, Del. Its toughness is expected to provide an outstanding durability, exceeding that of leather. The sheeting can be made in any thickness desired, given any grain or finish and manufactured in a variety of color. It has good flexibility and resistance to heat, moisture, and attacks by insects and mold.

Types of Strain Measuring Devices And Their Range of Utility

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Battelle Memorial Institute

Data are presented for selecting the proper extensometer, strain gage, or strainometer to suit a given application, particularly in the field of metallic materials. This survey of types of instruments and their limitations is based upon the author's experience with the different strain gages used at Battelle Memorial Institute.

STRAIN GAGES can be variously classified. One system given by Langer in "Design and Applications of a Magnetic Strain Gage," Experimental Stress Analysis, Vol. 1, No. 11, pages 82-89, lists the types according to the physical principle on which they are based. But the engineer or designer, is primarily interested in getting a particular job done; regard for scientific principles is secondary.

To get a job done properly, the requirements of the particular problem must be known. The elements in most problems are: Accessibility of the specimen; type of surface, flat or curved; gage length available; the range, sensitivity, and accuracy required of the strain-measuring device; the effect, if any, when the specimen is attached to the instrument; whether steady, transient, or cyclical strains must be evaluated or eliminated; how much skill and patience is required to attach and use the instrument; and where to obtain manufacturers' data, or other pertinent technical information.

Assuming that enough is known in a general way about the material to be tested, whether metallic or nonmetallic, to anticipate strains of 0.01, 0.1, 1, or 10 percent, the characteristics shown in Table I can be used as a guide to the comparative performance of a wide variety of extensometers. The table notations, although having been checked by the manufacturers, must be considered as contingent upon prevailing testing conditions and type of auxiliary equipment, such as micrometer type and comparator magnification.

Treated as values under good, but not exceptional, testing conditions, the tabulated data are reasonably reliable. The instrument mentioned is not necessarily the only type made by that particular manufacturer, but is the one that is in general use. The listing is in descending order of sensitivity. No attempt is made to draw fine distinctions between instruments of approximately equivalent sensitivity.

Additional Limitations and Adaptations

Extensometers that have mechanical lever systems have the advantage of simplicity, compactness, and fre-

Fig. 1—A roller-type gage for measuring large deformations on sheet specimens. Load and strain readings can be taken simultaneously.

Table I—Characteristics of Strain Measuring Devices

Name of Device	Type	Principle	Type Strains Best Adapted (in Steels)	Specimen Types	Usual Gage Length (Inches)	Approx. Smallest Measurable Strain (Microinches per Inch)	Approx. Range of Strains, Percent	Adaptability to Recording	Reference
"SR-4" Bonded Electric Strain Gage	A-1	Electrical resistance	Elastic	Flats 0.5×1 in. or greater. Curved surfaces greater than 1 in. radius on length or 0.5 in. on width	1 (6 to $\frac{1}{16}$ in. on other types)	0.5	1 (static loads)	Oscillograph, pen and ink recorders	Baldwin Locomotive Works, Bulletin No. 179
Tuckerman Strain Gage	0.2 in. lozenge	Optical lever	Elastic	Almost any round or flat surface, with suitable attachment	1 or 2	2 on 0.2 in. lozenge	0.25 on 2 in. g. l. (without reset)	Not possible, except by special adaptation	American Instrument Company, Bulletin No. 2084
General Motors Gage		Grids and photo-electric cell	Elastic	Any round or flat, with suitable attachment	$\frac{1}{8}$ to $\frac{1}{4}$	2		Oscillograph	Gadd and Van de Grift Trans. A.S.M.E. V. 64 (1942) p. A-15
Interferometer Types		Light wave interference	Elastic	Depending on adaptation		2	About 1	Special adaptation required	
Statham Unbonded Wire Resistance Gages		Electrical resistance	Elastic	Any surface, with suitable attachment	$\frac{1}{2}$ to 6	4 on 2 in. g. l.	Depending on attachment	Oscillograph	Statham Laboratories Catalog
Magnetic Gage	Westinghouse, small size	Magnetic	Elastic	Any round or flat, with suitable attachment	3	5	About 1	Graphic meter or oscillograph	Langer (article), Experimental Stress Analysis, Vol. I, No. II, pp. 82–89
Whittemore	10 in. gage length	Mechanical lever	Elastic	Flats of over 10 in. in length	10	10	1	None	Baldwin Locomotive Works, Bulletin No. 167
Huggenberger Tensometer	A	Mechanical lever	Elastic	Any round or flat, with suitable attachment	1	10	1	None	Baldwin Locomotive Works, Bulletin No. 139
Templin	T-1	Mechanical lever (non-averaging)	Elastic	Rounds 0.05–0.505 in. dia., flats 0.01–0.50 in. thick × 0.50 in. wide	2	20 with 1000 magnification	2	Selsyn motors and rotating drum	Baldwin Locomotive Works, Bulletin No. 162
Peters	P-1	Mechanical lever (averaging)	Elastic	Rounds 0.505 in. dia.	2	20 with 1000 magnification	2	Selsyn motors and rotating drum	Baldwin Locomotive Works, Bulletin No. 162
Olsen Electronic	YUAAR	Magnetic	Elastic	Rounds or flats, $\frac{1}{8}$ to 0.505 in.	2	20 with 1000 magnification	2	Special amplifier and revolving drum	Tinius Olsen Testing Machine Company, Bulletin No. 24
Porter-Lipp		Mechanical lever	Elastic	Any surface, with suitable attachment	1	20	0.5	Special adaptation required	P. L. Porter, 226 Oceano Drive, Los Angeles 24, California
Riehle	Averaging dial type	Dial gage	Elastic and early plastic (averaging)	Rounds or flats, $\frac{1}{8}$ to $\frac{5}{8}$ in.	2	100	2.5	Special adaptation required	American Machine and Metals, Inc., Bulletins
Berry Strain Gage		Mechanical lever	Elastic or plastic	Flats of over 10 in. in length	10	50 on 10 in. g. l.	About 1	None	Davis, Troxell, and Wiskocil
DeForest Scratch Gage		Mechanical trace	Elastic and early plastic	Any flat surface	2	100	2.5	Scratch pattern on special plate	Waugh Laboratories Bulletin on Strain Measurements
Amsler		Dial gage	Elastic and early plastic	Rounds 0.02 to 1.5 in. dia. Flats to 1.5 in. wide and to 1.5 in. thick	2 to 10	100 on 2 in. g. l.	8	Special adaptation required	Alfred J. Amsler and Company, descriptive bulletin
Kenyon-Burns-Young	10 : 1 wedge	Wedge	Plastic	Flats up to $\frac{1}{8}$ in. thick and up to $\frac{1}{2}$ in. wide	2	500 with 20 magnification	45	Line from wedge around drum	Baldwin Locomotive Works, Bulletin No. 128
Photogrids and Comparator		Microscope comparator	Plastic	Any surface	0.01 to 0.25	Depending on objective and test conditions	About 40	Photography of pattern	O'Haven and Harding (article) Experimental Stress Analysis, Vol. II, No. II, pp. 59–70
Micrometer Caliper		Graduated screw	Plastic	Rounds and flats for transverse measurements	0.5	500 on 0.505 in. round	No limit	Special adaptation required	.....
Stresscoat	ST-103	Brittle coating	Elastic	Any surface	very small	500	0.5 to 0.15	Photography of pattern	Magnaflux Corporation, ST-103 data sheet
Riehle Percentage Gage	2 in. gage length	Vernier	Plastic	Any surface prepared by punch marks	2	1000	70		American Machine and Metals, Inc., bulletins
Photoelasticity		Polarized light	Elastic	Transparent plastic model	Very small	Depends on model and testing conditions	Elastic region	Photography of pattern	Frocht (book) "Photoelasticity"

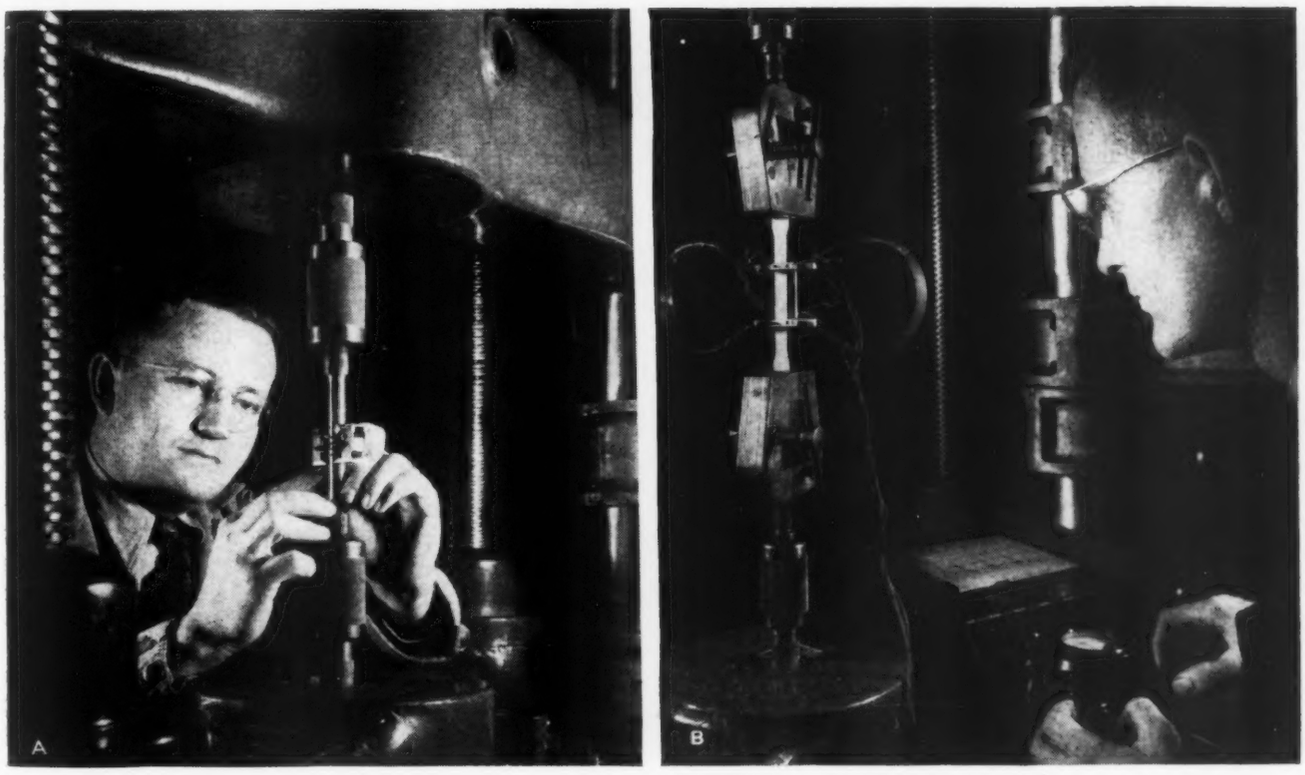

Fig. 2—(A) Placement of Tuckerman extensometers for averaging out bending stresses. This type of strain gage combines high sensitivity with accuracy. (B) A special construction using SR-4 electric resistance gages to measure plastic deformation. Special constructions are often necessary to meet unusual problems.

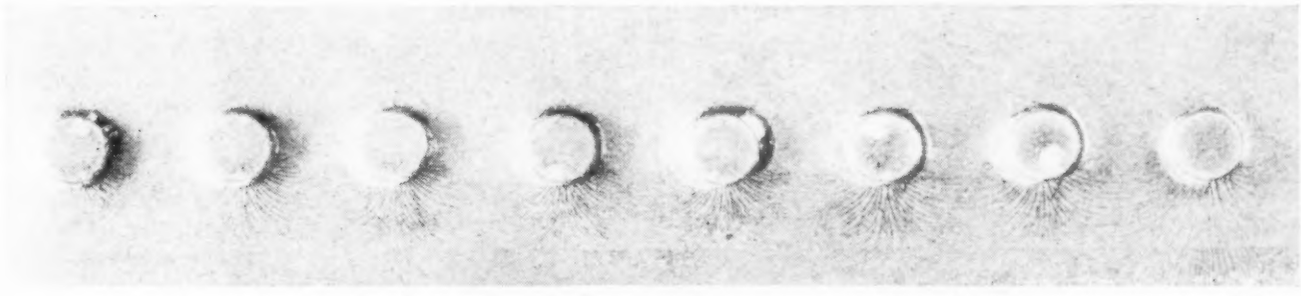

Fig. 3—Stresscoat pattern of single-riveted Alclad lap joint.

quently, ease of manipulation. They are subject to pivot friction, and their sensitivity is limited by the weight of the levers themselves. The inertia of the levers results in errors caused by vibration, and precludes the use of such extensometers in many dynamic measurements.

Dial gages, a special type of mechanical lever, have an additional advantage of ease of reading, but calibrations are usually unstable and need frequent checking for reliability.

Optical extensometers overcome some of the limitations of mechanical levers, and lend themselves readily to precision work. They are distinctly laboratory instruments and much patience must be exercised in their manipulation. The images are not readily brought into view, and many users will find prolonged peering through an optical device tiring to the eyes over long periods. But for high sensitivity combined with high accuracy in absolute measurements, optical devices, such as the Tuckerman strain gage, are foremost.

Electrical-resistance gages, whether bonded or unbonded, allow measurements of dynamic strains and permit observation by remote control. Temperature effects frequently are a source of impaired sensitivity, but, for many applications, this limitation is not a serious one.

The magnetic types have the advantage of ruggedness. With these types it is possible to use larger measuring currents than in the resistance types, making amplifiers unnecessary for many purposes. Lack of linearity of response is a drawback except in types that feature an automatic motor-driven follow-up, as in the Olsen Electronic type.

Brittle coatings, such as Stresscoat, are useful in giving a qualitative strain picture, including strain orientation, over an extended area. "Sore spots," indicating where a more sensitive gage should be placed, are shown. Such coatings have very small effective "gage length" and facilitate examination of regions containing fillets, notches, or other abrupt changes in section.

Photoelastic methods are used to advantage in the design of parts to avoid stress raisers, and in other applications

in which the saving gained in a large number of production units justifies the effect expended in making plastic models.

Interferometer types are very difficult to manage and are definitely out of place in most routine work. Although in the laboratory, measurement of small strains can be rendered with high precision.

The wedge type, known as the Kenyon-Burns-Young extensometer, is one of the few suitable to measure the larger plastic deformations. Wedge friction, in the transition from a stationary load to a changing load, introduces an element of uncertainty into more precise applications. It is important to check the line to the drum for any slack around pulleys as the test proceeds.

Grids, either scribed or photographic, used with a comparator for measurement are also utilized to advantage in the plastic region of metals. Means for measuring large plastic deformations are extremely few and possess numerous limitations. The growing interest in the subject, makes it appear that this is an open market for instrument makers.

An averaging-type extensometer for precision modulus determinations and types designed for operation at elevated temperatures to 200 deg. F. are other items for which need exists.

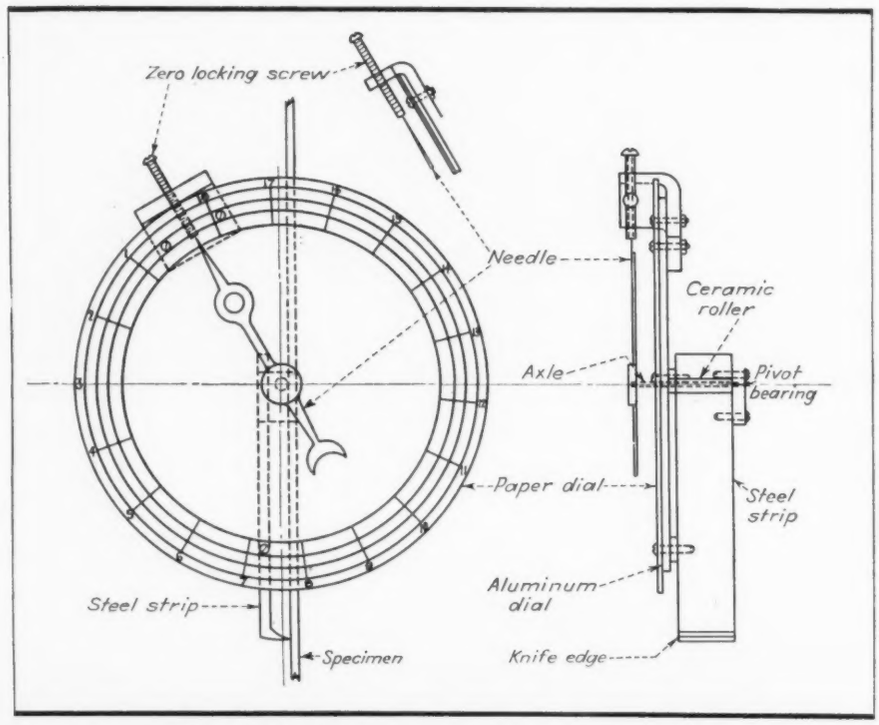

Fig. 4—Special extensometer for plastic strains.

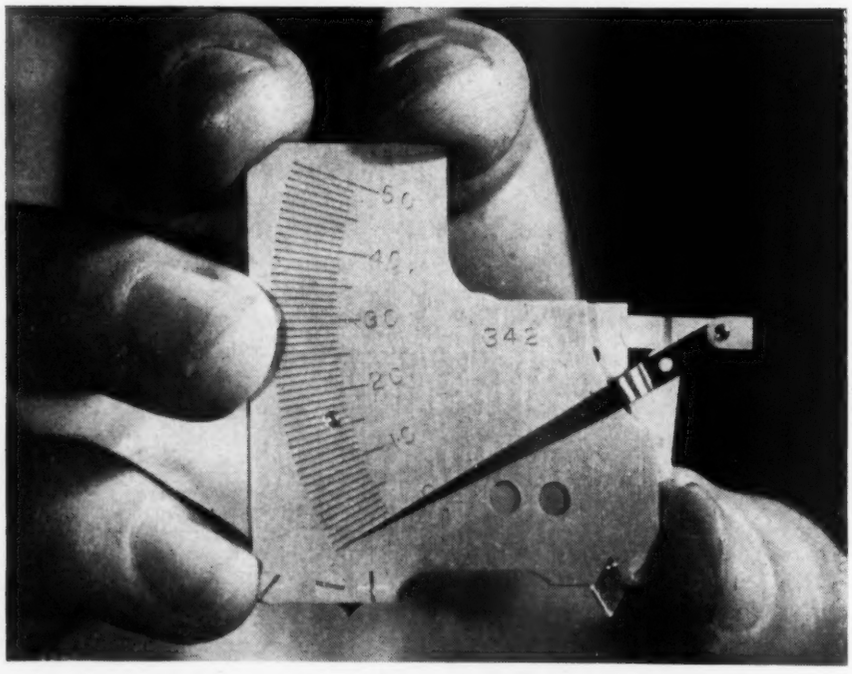

Fig. 5—Close-up of the four-ounce Porter-Lipp extensometer.

Special Constructions

With many problems, specially designed instruments are necessary. For example, the problem of measuring large plastic deformations on certain sheet materials has been met at Battelle Memorial Institute by the construction shown in Fig. 4. A small roller of unglazed ceramic material was attached to a knife edge and clamped against the flat specimen in position such that elongation of the specimen resulted in rotation of the roller. The axis of the roller carried an indicating needle, and the dial was marked off into equal segments. The gage length remained constant during elongation of the specimen, and, as a result, the equal segments represented "true strain", accordingly defined as

$$\text{True Strain} = \log_e \left(\frac{l}{l_0} \right)$$

where l is the instantaneous length; and l_0 is the original length set off by the gage points.

Other special constructions make use of SR-4 resistance gages as measuring elements on an auxiliary framework attached to a specimen surface. The framework is usually adapted to meet the individual requirements of the problem at hand.

Occasionally it is convenient to utilize an auxiliary framework in conjunction with a traveling microscope when extraneous vibrations are not present. Even when vibration is present, it is sometimes possible to damp out the oscillations by attaching small paddles to the sighting points and immersing them in an oil bath.

Many constructions utilizing other instruments are possible, depending on which limiting factors and handling characteristics are most nearly suited to the requirements of the problem in question.

Progress IN REVIEW

PLASTICS

Honeycomb core materials for "sandwich" construction, until recently limited to flat sheets, are now being fabricated in curved sections. The internal assembly of the "honeycomb cells" affects the final shaping of the sheet, certain cell shapes being especially suited for certain final forms. It has been found, according to *Modern Plastics,* Oct. 1946, that hexagonal-shaped cells are best for saddle-backed forms; square-patterned cells for single curvatures, and trapezoidal cells for double curvatures or domed shapes. In line with this development, the article, "Theory of Sandwich Construction" by A. Garrard appearing in the Sept. and Oct. issues of *British Plastics,* discusses technical factors pertinent to the selection of core materials, density of cores, strength-weight-bulk relations, and use of "sandwiches" in long versus short columns. Further indicative of the growing popularity of this technique is the recent development at Wright Field of "sandwich" constructions for airplane wings. The cellular cellulose acetate core boards covered with glass fiber-base laminates are reported in *Plastics News Letter,* Nov. 4, 1946 to satisfactorily withstand the required loads and should permit greater speeds because the smooth surface, free from rivets or bolts, decreases air resistance.

Coefficient of thermal expansion values for plastics can be reduced to those of metals to avoid the destructive effects of unequal expansions by the addition of fillers having lower expansion coefficients. The type and quantity of filler to be added can be determined from a theoretical relationship of the density, modulus of elasticity, coefficient of expansion, and proportion by weight of each constituent in the proposed mixture. The practical application of this relationship has been verified by laboratory investigations on brass inserts in styrene; the use of plastics for filling rivet depressions, and the optimum amount of resin in phenolic resin-glass fiber combinations. These experiments are discussed in the article, "Thermal-Expansion Stresses in Reinforced Plastics," by Philip S. Turner in the *Journal of Research of the National Bureau of Standards,* Oct. 1946. Also with the objective of overcoming the deleterious effects of high thermal expansion, wartime research at the Massachusetts Institute of Technology resulted in new plastic compositions of exceptionally low thermal coefficients. Among these are Polyglas P, D, and S with coefficients as low as 1.3×10^{-5} per deg. C. as compared to unfilled phenol formaldehyde with 2.5 to 6.0×10^{-5} per deg. C. The simplest of these is Polyglass S, as described by A. von Hippel and L. G. Wesson in the article, "Polystyrene Plastics as High-Frequency Dielectrics", in the Nov. 1946 *Industrial and Engineering Chemistry.* Polyglas S consists of a polystyrene resin, special electrical-grade glass filler, and slight additions of moisture-proofing agents, paraffin wax and silicone grease.

Airplane propellers, long-plagued by conditions of weather, humidity and abrasion, are now made more resistant to these inclemencies by a carefully applied film of black cellulose nitrate. This process, discussed by Sidney H. Fedan in "Nitrate Covering for Propeller Blades," *Modern Plastics,* Nov. 1946, was first used by the Germans in 1936 and was developed in the U. S. in 1943 for military purposes.

Resin suppliers have extensively publicized the use of resins as sealants for porous metal castings. Vernon G. F. Holm in "A Study of Resinous Sealants for Porous Metal Castings," *Journal of Research of the National Bureau of Standards,* Sept. 1946, states that although cast bushings of aluminum, copper-silicon alloy, and red brass were impregnated with fourteen types of resinous sealants, none of the sealants were effective on more than 80 percent of the treated specimens even after a two-dip impregnation. Vigorous tests included the application of fluid pressure at 600 lb. per sq. in. and at temperatures to 700 deg. F., immersion in oil at 250 deg. F., immersion in high octane gasoline at room temperature and also in boiling water. Apparently the resin sealing technique without using pressure is useful in emergencies. However, impregnating with sealants under pressure has and is being used extensively and successfully. See "Sealants for Metal Castings for Varying Degrees of Porosity", PRODUCT ENGINEERING, Jan. 1945. The problem of eliminating porosity in metal castings is one of better design, judicious selection of alloys, and the application of improved foundry practices.

Annealing can overcome the failures caused by thermal or mechanically induced strains in styrene parts. Unlike metals, the annealing of styrene is not to be confused with orientation nor with any considerable change in state, according to James Bailey in "Annealing of Styrene and Related Resins," *Modern Plastics,* Oct. 1946. The annealing of styrene is a simple release of thermally induced strains similar to those in glass. Incidentally, styrene chemically modified slightly to make it cross-linking, can be added to vary the flexibility characteristics of elastomeric Vistanex. After polymerization, a mechanical combination similar in principle to reinforced concrete is produced. It is claimed in *Industrial and Engineering Chemistry,* Nov. 1946 that the polystyrene forms a relatively rigid network within the resilient mass of the Vistanex and that by adjusting the ratio of the two components, any desired degree of rigidity can be obtained. The method was developed for wire-coating material, but is believed to be useful for many applications.

Glass fiber mats impregnated with contact resins of the styrene-polyester type can be molded to produce physical properties that are superior to high impact grade molded phenolic materials, definitely superior to cotton-base laminates,

and nearly equivalent to glass cloth laminates. This method is claimed in *Pacific Plastics,* Oct. 1946 to require inexpensive dies, no presses, and almost no finishing of the molded pieces.

Plastics now permit the mass production of intricate prisms and lenses formerly made by laborious hand methods, polycyclohexyl methacrylate and polystyrene being the best for these optical purposes. The refractory index of polycyclohexyl methacrylate is similar to that of crown glass and it can be cast into accurately-shaped optical parts of uniform clearness and optical homogeniety. Two drawbacks, however, are its low softening temperature of about 70 deg. C. and its comparative vulnerability to scratching and abrasion. Styrene, used in combination with polycyclohexyl methacrylate parts, produces achromatic systems superior to those designed from glass combinations. Although styrene has a slightly yellowish tinge, its high refraction index makes it particularly valuable for lightweight prisms where high refraction is important.

Carbon black, essential for reinforcing the GR-S tire compounds, is available in new and modified forms that give more efficient, cooler running carcasses and have greater resistance to tread cracking. These same advantages are claimed for a new research development, a white reinforcing material, that functions in much the same manner as carbon black by embellishing the physical properties of a vulcanizate. In line with this, recent tests conducted under desert temperature conditions at high speeds, showed butyl inner tubes to be vastly superior to natural rubber inner tubes in air-holding ability.

Phenolic resins, always considered as good adhesives in their own right, are now being blended with synthetic rubbers to form adhesives of exceptionally outstanding quality. These are finding ready use in the bonding of similar or dissimilar materials and provide excellent adhesion, especially under conditions where moisture is prevalent.

Injection molding, heretofore limited to small parts, is now being successfully used for producing exceptionally large hard rubber pieces as the result of new press equipment available. This makes possible the production of mechanical rubber goods parts having superior physical properties and at the same time allows a reduction in curing time cycles. A higher degree of accuracy for precision parts having rubber to metal adhesion inserts is likewise attained.

NONFERROUS METALS

Magnesium, obtainable from dolomite and magnesite ores, from subterranean brines, from waste liquors of potash manufacture, and from sea water, is rapidly taking a place in the foremost ranks of the nonferrous engineering materials. A sixteen-page insert in the Nov. 7 issue of *American Machinist* presents recommendations and data on the machining, sheet-working, casting forging, joining, and finishing of this lightweight material. Alloying constituents extend still further the usefulness of the metal, which was discussed at the Third Annual Meeting of the Magnesium Association recently held in New York City. It was reported that zirconium, added in small percentages, greatly reduces the grain size and facilitates cold-rolling of magnesium alloys and that the reduction in grain size resulting from this addition of zirconium insures increased soundness in sand castings.

Silver solder, containing 85 percent silver and 15 percent magnesium and withstanding temperatures comparable to those inside gas turbines, is announced in Report PB23086 by the Office of Technical Services of the Department of Commerce. Recommended for silver-soldering stainless steel and other materials used in heat exchangers, exhaust manifolds, gas turbine parts, and general chemical equipment, this alloy melts at 1,790 deg. F. and is claimed to retain its strength to 850 deg. F.

Copper base alloy castings are greatly affected by glass and oxides. This subject was discussed in The Foundation Lecture for 1946, presented by G. H. Clamer before the Fiftieth Anniversary Convention of the American Foundrymen's Association. The author described the research project on this problem originally undertaken at Battelle Memorial Institute. It was found necessary to standardize test bar design before these studies could be started. Complete test bar practices are now being formally standardized both by the American Foundrymen's Association and by the American Society of Testing Materials. A paper presented at the Foundry Conference in Lansing, Mich. compared of investment castings, plaster-mold die castings, permanent mold castings and centrifugal castings. In line with this is the discussion on precision casting of heat-treatable copper-base alloys in the Sept. 19, 1946 issue of *Iron Age* by Messrs. Rosenthal, Lipson, and Markus of the Frankford Arsenal Ordnance Laboratory, who have developed a technique for obtaining the physical properties of wrought beryllium-copper and cast aluminum bronze in precision investment castings. These physical properties are obtained by quenching the parts immediately after solidification of the molten metal and then reheat-treating at a low temperature.

Permanent mold castings now constitute more than 20 percent by weight of all the aluminum castings shipped from foundries. This increase in use is partially attributable to the better pressure tightness that can be obtained after machining than can be obtained with die castings. W. F. Schleicher, in the Oct. 3 issue of *Iron Age* discusses this and further points out that permanent mold castings are stronger and have greater density than sand castings. Machining costs are less than for sand castings and die costs are less than those for die castings.

Aluminum and its alloys, long limited to either a natural silvery finish or various colored finishes, can now be treated to very closely resemble brass and chromium by an electrochemical process. The finished surfaces have good corrosion and abrasion resistance, do not require after-lacquering, and result in highly reflective mirror effects.

Minimum bending radii for five aluminum-base alloys in strip form were presented by Messrs. Gohn and Arnold in a paper before the Annual Meeting of the American Society of Testing Materials. The same authors present comprehensive data on the fatigue characteristics of beryllium copper strip in the paper "The Fatigue Properties of Beryllium Copper Strip and Their Relation to Other Physical Properties." Both of these papers will be published in the 1946 *Proceedings* of the American Society of Testing Materials.

Industrial Research is a gamble, according to R. P. Soule, vice president-in-charge of Research and Development for the American Machine & Foundry Company, but not to engage in industrial research is the biggest possible industrial gamble. Charting the past trends in industrial research, in his address before the New England Research Conference of the New England Council, Mr. Soule predicts that the next 20 years will be marked by research that can best be described as functional engineering with an increased emphasis on the principle of composite construction making wide use of combinations of metals and non-metals.

Improved Mechanical Test Methods For Better Plastics Design

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Research and Development Department, Bakelite Corporation

Modifications of the standard flexural and impact tests for molded plastics are proposed. Impact evaluation as an area under a flexural curve is demonstrated. Relation of notched and unnotched specimens to finished product is discussed.

GREAT RELIANCE is placed on the standard mechanical tests for plastics materials, with the result that these tests are subject to critical review. The standard tensile, flexural and Izod impact values for plastics are determined carefully by techniques that resemble those used for metals. Yet it is generally agreed that the results do not always apply to practical conditions. One material may be stronger than another in the flexural test but weaker in the molded object. The same is true for impact values, except that the discrepancies are more frequent. Moreover, a material that has a good flexural strength may show a low impact test value. These difficulties arise because mechanical tests used for plastics are based on tests that were developed specifically for steel.

The Izod Test

The Izod test for plastics is similar to that for steel except that the machine is much lighter and the specimen is slightly different. The specimen is a notched rectangular bar (Fig. 1) clamped in the plane of notching. The impact energy is consumed in three ways:

1. Breaking the specimen.
2. Deforming the machine base and fittings—so-called machine losses.
3. Throwing the broken end of the specimen—frequently to a distance of several feet.

For practical purposes and as an aid in product design, only the energy consumed in breaking the specimen should be considered.

A recent investigation with electronic techniques (L. E. Welch and H. M. Quackenbos, Jr. *Trans. A.S.M.E.* July, 1946) allows an estimate of the way in which energy is distributed along the three channels. Data for phenolic molding materials are presented in Table I. It is evident that the real impact (stress-strain) energy is only a small percentage of that actually measured in the Izod test. Further, this percentage varies widely so that there is no fixed relation between the real and the Izod value. Consequently the Izod impact strength is of limited application.

Table I—Distribution of Energy in Izod Test For Thermosetting Phenolic Molding Materials Notched Bar

Filler	Izod Impact Strength	Energy Breaking Specimen	Dissipation, percent		Real impact Strength ft.-lb.
			Machine	End Effect	
Woodflour	0.16	10	29	61	0.016
Mineral	0.15	7	32	61	0.011
Fabric	1.5	12	88	0	0.18
Kraft	0.29	10	73	17	0.029
Floc	0.23	10	62	28	0.023

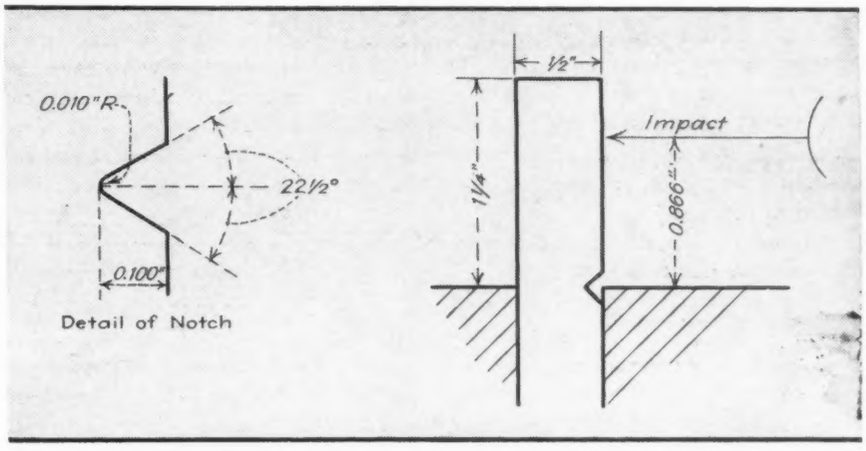


Fig. 1—Detail of Izod specimen and point of striking.

The real impact energy is the area under the load-deflection curve in the impact test. The same investigation brings out that for most phenolic materials, the load-deflection curve is the same whether loading is rapid as in the impact test or gradual as in a flexural test. The same conditions are believed true for most thermoplastics and laminates that are essentially elastic to failure (load-deflection curve linear to the point of failure),

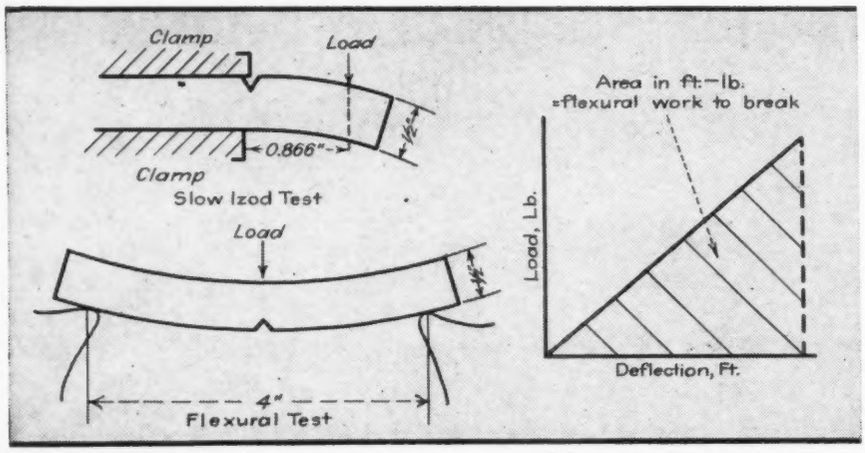


Fig. 2—Slow loading of Izod specimen and similar bending loading in flexural test. Area under load-deflection curve in flexural test is flexural work to break.

although little data has been gathered in this field. Where there is ductility, appreciable departure from elasticity, a correspondence between the two types of loading may exist. But the evidence is as yet insufficient to warrant a conclusion.

Thus with most plastics materials, which are virtually non-ductile, the the energy represented by the area under a curve of load versus deflection under slow loading can be taken as the true impact valve. This is the slow Izod test shown in Fig. 2. Both the flexural test and the slow Izod test are bending tests and give the same comparative results. True impact energy can thus be taken as the area, in ft.-lb. ordinates, under a load-deflection curve of a notched bar loaded in flexure.

Although flexural area for a notched bar, like tensile strength and flexural strength, is a test value free from errors, such data cannot be applied with confidence to product design. The reason for the breakdown in practice of flexural area (notched), tensile strength and flexural strength is misapplication of result.

Proper Application of Test Data

How can test valves be properly applied? The answer lies in appreciating the effect of a notch.

When a chemist wants to break glass tubing he puts file scratch on the outside. In this way the glass is weakened considerably, although the depth of the scratch is quite shallow compared with the thickness of the wall of the tube. In an actual flexural test on glass tubing it took an average of 82 lb. to break the unscratched tube and only 21 lb. to break the scratched tube. The scratch brought the strength down to ¼ its original value.

It follows that tensile, flexural and impact tests must be carried out on a specimen that resembles the object that is to be made from the glass. If the tests are on unscratched specimens and the object is scratched then it will be much weaker than expected; the reverse would also be true. Further, the weakening effect of the scratch is duplicated by other surface discontinuities such as sharp corners, small holes, notches and screw threads. A glass object containing one of these will behave in a manner predicted by tests on a scratched specimen rather than on one that is not scratched.

It is not always appreciated that the notch effect occurs with all materials although usually to a far less serious degree than with glass. This effect varies considerably with metals and plastics. With mild steel and a fabric-filled phenolic material the notch causes little or no weakening. On the other hand hardened tool steel and woodflour-filled phenolic materials are affected to a marked extent. The only way to establish the characteristics of a material is to make tests on notched and unnotched specimens.

Tensile and flexural values for plastics materials are determined on unnotched specimens and they apply only to objects free of notches, holes, corners and other depressions. Similarly the impact evaluation, flexural area, is made on a notched specimen and applies only to objects containing notches or similar cut-outs. Tests have fallen into disrepute because they have been applied indiscriminately to molded objects of all kinds.

Tensile and Flexural Strength

A notch weakens a bar in two ways: By reducing its thickness and by virtue of the notch effect. This latter varies with the radius at the apex of the notch. Fig. 3 shows the way in which the breaking load of a notched bar (*A*) becomes greater with increasing radius. When the notch radius be-

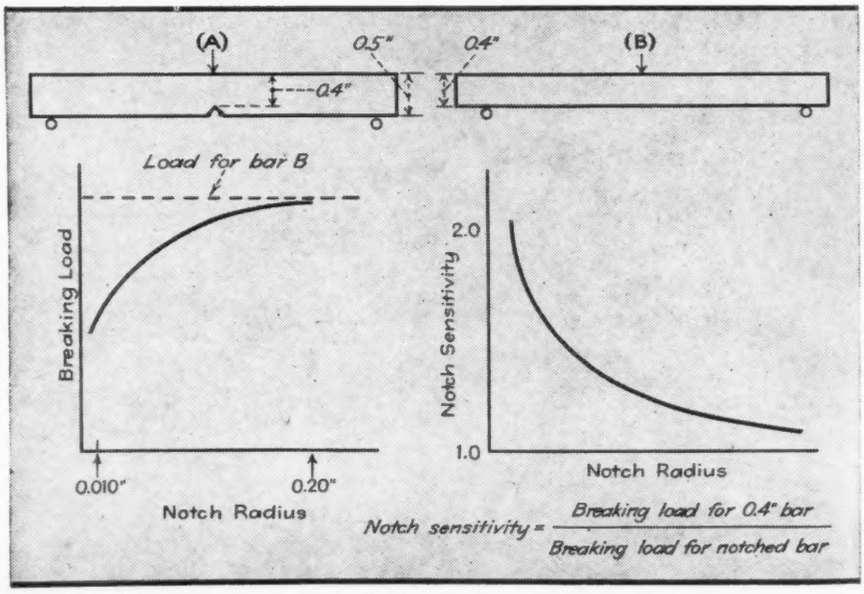


Fig. 3—Flexural tests on bars having notches of varying radii, from sharp radius (A) up to infinite radius (B). Plots of breaking load and notch sensitivity versus notch radius.

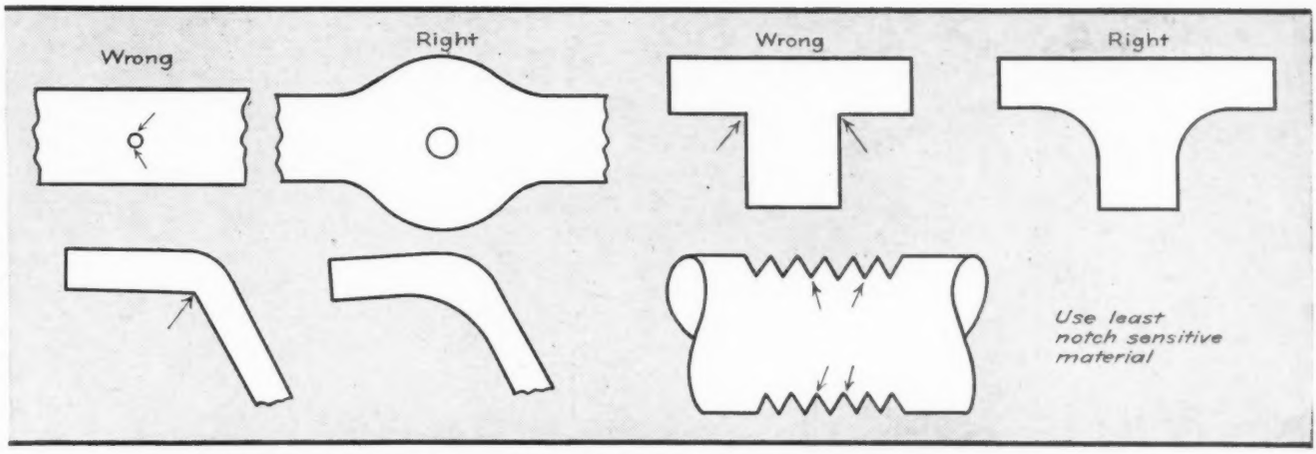


Fig. 4—Right and wrong design. In right design sharp corners, holes, and corners are avoided.

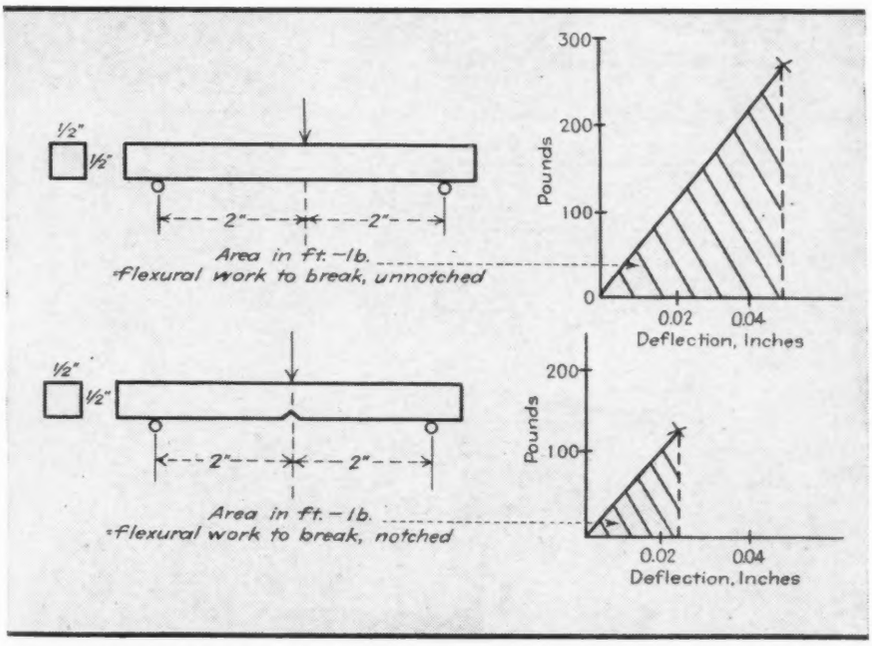


Fig. 5—How flexural work to break unnotched, and flexural work to break notched, are determined from load-deflection curves in flexural test.

comes infinite the breaking load in that of bar (*B*), as shown. Notch sensitivity, as defined in Fig. 3, is a measure of the notch effect only and does not include the weakening caused by the reduction in depth resulting from the notch. This latter is easily estimated, from the usual flexural formula, from the ratio of the square of the depths.

How are flexural strength and tensile strength to be used in conjunction with notch sensitivity? Table II gives some notch sensitivity values for a few common plastic materials with a notch of 0.010 in radius. Evidently the effective flexural strength for an object containing such a notch is the orthodox flexural strength divided by the notch sensitivity. The effective tensile strength is calculated in the same way with the same notch sensitivity. The list of effective flexural strengths demonstrates that some materials are much more severely affected by the notch than others. When the filler is fabric the notch has no weakening effect. Consequently orthodox flexural strength can be dangerously misleading when applied to a notched object.

In practice then, two suggestions are offered: First, estimate the radius of notch, hole or corner in the molded object and rate materials on the basis of their effective flexural or tensile strengths at that radius. A typical curve relating notch sensitivity to notch radius to permit such a calculation is given in Fig. 3. Second, avoid, if possible, notches and their equivalents in the molded object, Fig. 4, or minimize their effect by making the radius as large as possible.

Impact Resistance

The improved impact evaluation, flexural area, is the area under a load-deflection curve of a notched bar in flexural loading. As the notch radius decreases from wide to sharp the breaking load tends to drop as illustrated in Fig. 3. This decrease in breaking load is accompanied by a decrease in total deflection; thus the flexural area, depending on the product of these, is much more severely reduced than the breaking load alone. Whereas the flexural strength is divided by the notch sensitivity to give the effective value, the flexural area with decreasing notch radius follows a curve in which square of notch sensitivity is the divisor.

Impact loading, however, is generally accidental and unpredictable. One never knows what part of a falling molded object will hit the floor first or conversely just where something will be dropped on to the object. Instead of using an effective flexural area at each notch radius, the problem can be simplified by using two values of flexural area. One is for an unnotched bar, the other for a bar containing a sharp notch having a radius of ten mils. These are called, respectively, flexural work to break, unnotched; and flexural work to break, notched; and are evaluated, Fig. 5, simply as flexural

Table II—Notch Sensitivity and Its Effect on Flexural Properties For Some Common Plastics Materials

Bar A is 0.5 in. deep and is notched 0.010 in. radius
Bar B is 0.4 in. deep and is unnotched.

Material	Bar B Breaking Load, lb.	Flexural Strength lb. per sq. in.	Bar A Breaking Load, lb.	Notch Sensitivity B/A	Effective Flexural Strength, lb.
Phenolic-woodflour	153	11,000	73	2.1	5,400
Phenolic-floc	162	11,800	124	1.3	9,100
Phenolic-mineral	108	7,500	68	1.6	4,700
Phenolic-kraft	152	11,000	117	1.3	8,500
Phenolic-fabric	184	13,400	184	1.0	13,400
Polystyrene	153	11,100	153	1.0**	11,100
Cellulose acetate*	108	7,500	108	1.0**	7,500
Lucite	138	10,000	138	2.5**	4,000
Cast phenolic (no filler)	138	10,000	40	3.5	2,900
Paper laminate	234	17,000	106	2.2	7,700
Cloth laminate	304	22,000	234	1.3	17,000
Fiberglas laminate	413	30,000	294	1.4	21,000

* Medium plasticizer content.
** Notch molded; machined notch usually gives much higher notch sensitivity, especially with polystyrene.

Table III—Notch Sensitivity and Flexural Work to Break

Molded notch, 0.010 in. radius. Milled notch increases notch sensitivity and reduces flexural work to break, especially with polystyrene.

Material	Izod Impact Strength ft.-lb. per specimen	Notch Sensitivity	Flexural Work to Break, ft.-lb. per specimen	
			Unnotched	Notched
Phenolic-woodflour	0.15	2.1	0.6	0.07
Phenolic-floc	0.3	1.3	0.7	0.2
Phenolic-mineral	0.15	1.6	0.2	0.04
Phenolic-kraft	0.23	1.3	0.5	0.12
Phenolic-fabric	1.5	1.0	1.0	0.9
Polystyrene	0.3	1.0	1.3	0.6
Cellulose acetate	0.46	1.0	1.0	0.4
Lucite (methyl methacrylate)	0.21	2.5	1.2	0.11
Cast phenolic (no filler)	....	3.5	1.2	0.04
Paper laminate	0.75	2.2	1.3	0.26
Cloth laminate	2.0	1.3	4.9	0.9
Fiberglas laminate	3.2	1.4	2.6	1.1

areas. The unnotched test is the standard A.S.T.M. flexural test.

Sample values of flexural work to break different materials are listed in Table II. These give quite a different comparison than the Izod test. There is no direct comparison between flexural strength and resistance to impact. With constant flexural strength impact resistance varies quite considerably among fabric-filled phenolic materials, woodflour-filled phenolic materials and the polystyrenes. This is because resistance to impact is a flexural area, Fig. 6, and depends not only on flexural strength but on modulus of elasticity, ductility and notch sensitivity.

Justifying Proposed Test Methods

The analysis given of the notch effect is not new. It has been known for years, especially in design with metals. Therefore, no practical demonstration is necessary of the suggested use of notch sensitivity in conjunction with the tensile and flexural strength of plastic materials.

With flexural work to break the situation is different. Flexural work to break has been recommended only a few times and notably by Hazen (T. Hazen, *Modern Plastics*, October, 1943) as a measure of impact resistance for plastics materials; with unnotched specimens of metals at low impact velocities it is more firmly established. In general, however, its worth has been based on empirical observations rather than scientific derivation, and its combination with notch sensitivity has not been appreciated. Some practical demonstra-

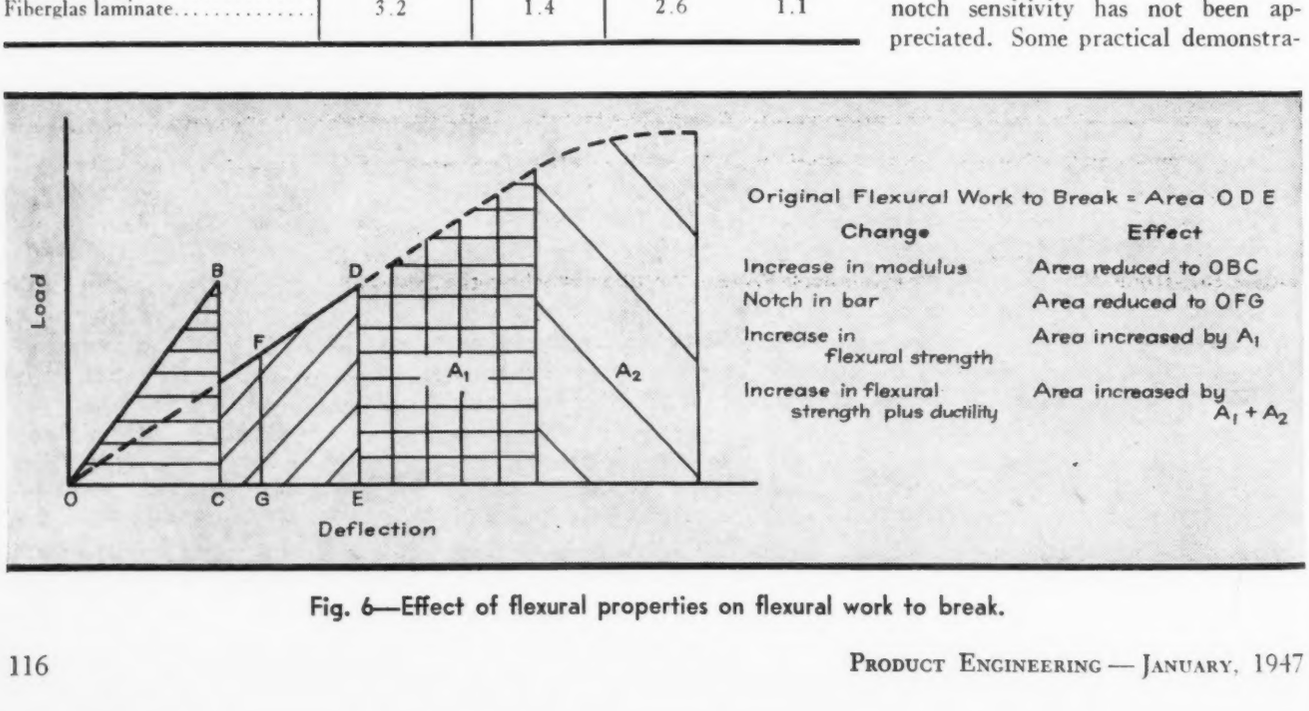


Fig. 6—Effect of flexural properties on flexural work to break.

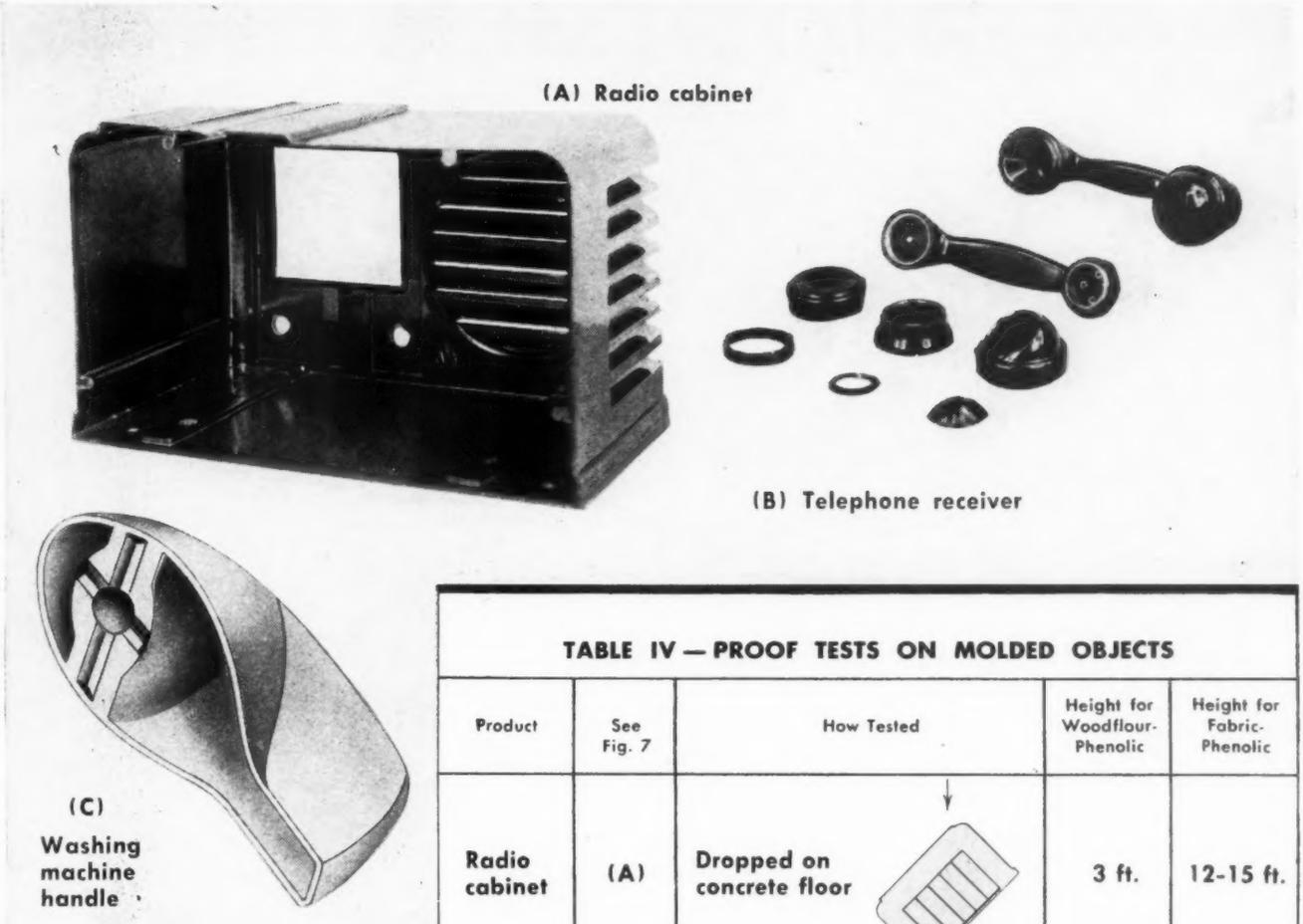


Fig. 7—Physical tests should be suited to design of molded objects.

TABLE IV — PROOF TESTS ON MOLDED OBJECTS

Product	See Fig. 7	How Tested	Height for Woodflour-Phenolic	Height for Fabric-Phenolic
Radio cabinet	(A)	Dropped on concrete floor	3 ft.	12-15 ft.
Telephone receiver	(B)	Dropped on concrete block	1*	1-2*
Washing machine handle	(C)	Weight dropped on it	1.3 ft.-lb.	3.3 ft.-lb.

*No units of height given because actual results depend on method of molding.

tion of the superiority of flexural work to break over the Izod value is thus needed.

The first such demonstration is seen in the mineral and woodflour phenolic plastics. Of the two, the woodflour composition nearly always gives the more rugged molded object. This is indicated by the flexural work to break both the unnotched and the the notched specimens, Table III; but the Izod test fails completely as a guide.

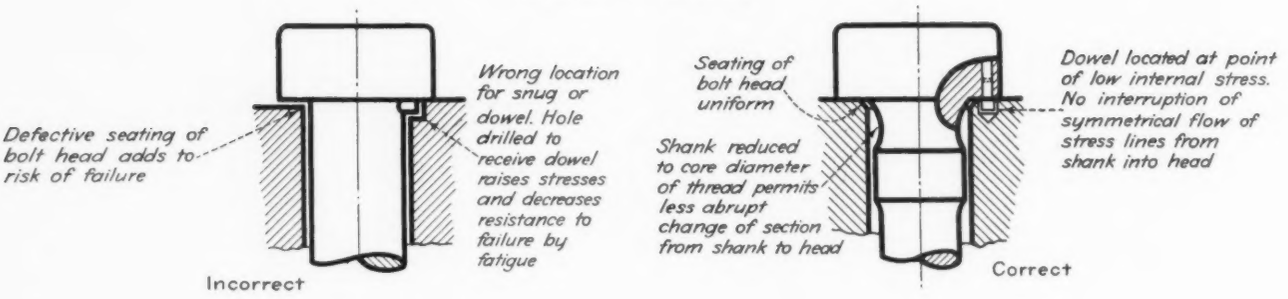
Comparing the woodflour and fabric phenolic materials, the Izod test predicts that the fabric material will be ten times tougher, Table III. In contrast the actual ratio of impact resistance of the molded object varies widely—from one to ten. This would be expected from the values of flexural work to break. The unnotched values are such that the fabric-filled phenolic is only a little better, whereas the ratio of the notched values is about thirteen to one in favor of the fabric-filled material, as compared to the woodflour-filled phenolic.

Actual tests on molded objects are summarized in Table IV for a radio cabinet, Fig. 7 (*A*); a telephone receiver, Fig. 7 (*B*); and a washing machine handle, Fig. 7 (*C*). The radio cabinet contains a variety of fairly sharp corners and, as expected from flexural work to break notched, is much weaker in impact when molded from the woodflour-filled material. The handle and the receiver contain a sharp corner or two but these are not in a region where a great deal of load is carried and the objects can be considered virtually unnotched. The flexural work to break, but not the Izod impact strength, indicates that the two materials (fabric and woodflour fillers) would produce molded objects of almost equal shock resistance; so it is found.

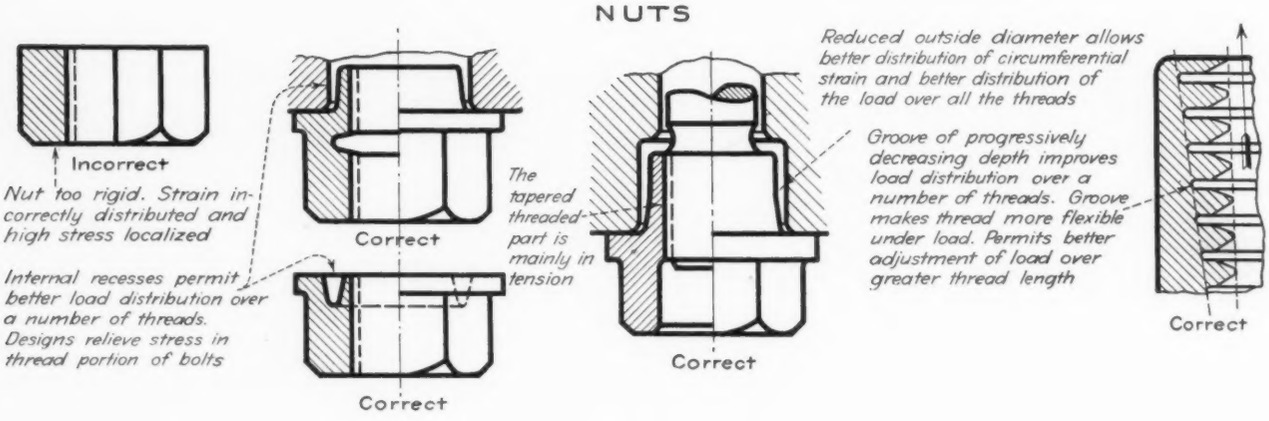
A wider adoption of the improved test methods will allow the designer to appreciate more fully the characteristics of plastics materials and to better select the proper plastics material which should be employed for a given application.

Design of Parts for Conditions

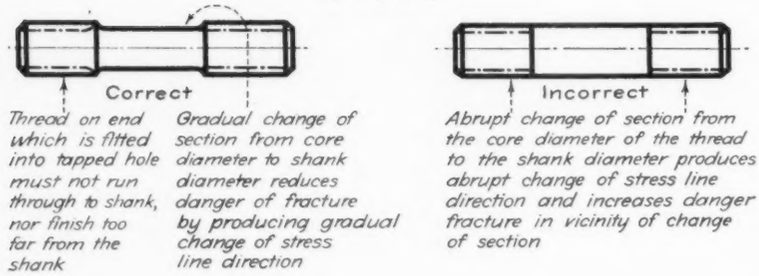
BOLT HEADS


Defective seating of bolt head adds to risk of failure
Wrong location for snug or dowel. Hole drilled to receive dowel raises stresses and decreases resistance to failure by fatigue
Incorrect
Seating of bolt head uniform
Shank reduced to core diameter of thread permits less abrupt change of section from shank to head
Dowel located at point of low internal stress. No interruption of symmetrical flow of stress lines from shank into head
Correct

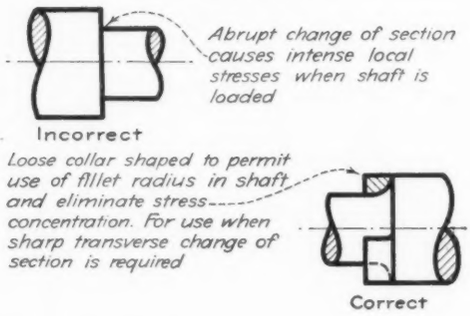
NUTS


Incorrect
Nut too rigid. Strain incorrectly distributed and high stress localized
Correct
Internal recesses permit better load distribution over a number of threads. Designs relieve stress in thread portion of bolts
Correct
The tapered threaded part is mainly in tension
Correct
Reduced outside diameter allows better distribution of circumferential strain and better distribution of the load over all the threads
Groove of progressively decreasing depth improves load distribution over a number of threads. Groove makes thread more flexible under load. Permits better adjustment of load over greater thread length
Correct

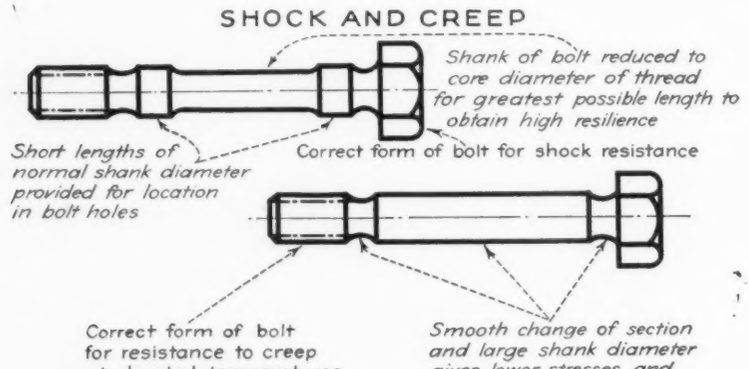
STUDS

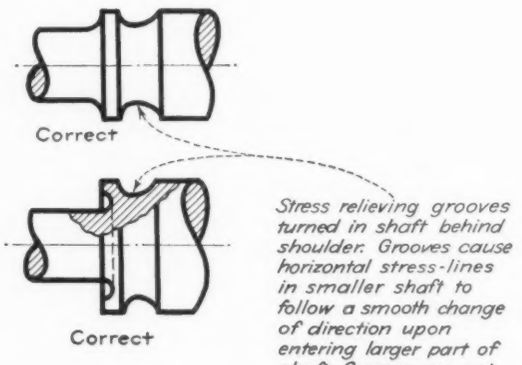

Correct
Thread on end which is fitted into tapped hole must not run through to shank, nor finish too far from the shank
Gradual change of section from core diameter to shank diameter reduces danger of fracture by producing gradual change of stress line direction
Incorrect
Abrupt change of section from the core diameter of the thread to the shank diameter produces abrupt change of stress line direction and increases danger fracture in vicinity of change of section

SHOULDERS


Abrupt change of section causes intense local stresses when shaft is loaded
Incorrect
Loose collar shaped to permit use of fillet radius in shaft and eliminate stress concentration. For use when sharp transverse change of section is required
Correct

SHOCK AND CREEP


Shank of bolt reduced to core diameter of thread for greatest possible length to obtain high resilience
Short lengths of normal shank diameter provided for location in bolt holes
Correct form of bolt for shock resistance
Correct form of bolt for resistance to creep at elevated temperatures
Smooth change of section and large shank diameter gives lower stresses and lower creep rate than a bolt with a reduced shank diameter

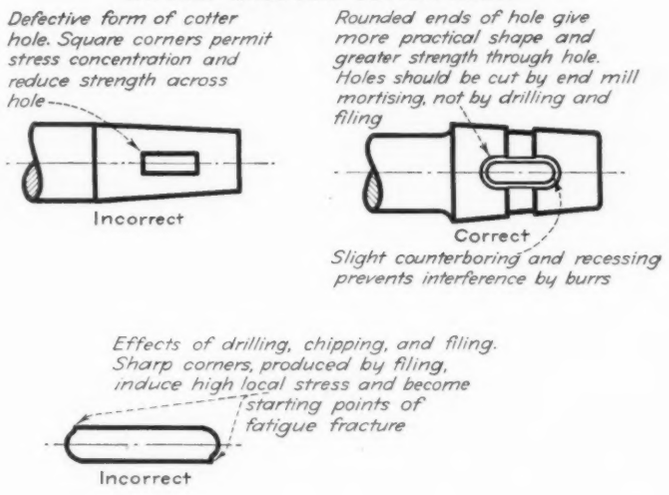

Correct
Correct
Stress relieving grooves turned in shaft behind shoulder. Grooves cause horizontal stress-lines in smaller shaft to follow a smooth change of direction upon entering larger part of shaft. Grooves are not semicircular in cross-section

Of Variable Stress

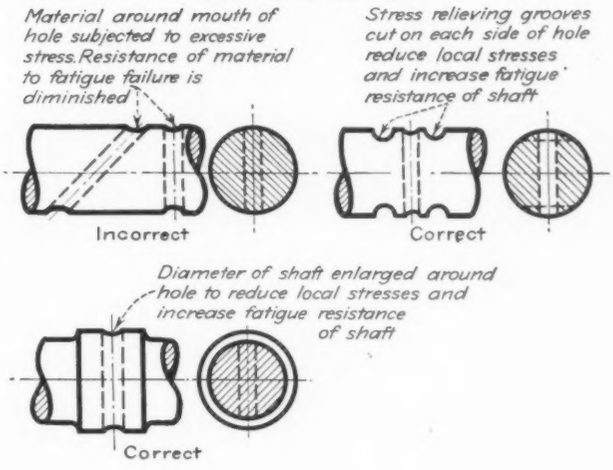
J. SELWYN CASWELL
Engineering Department, University College of Swansea

Load variations in machine parts are always accompanied by variations in internal stress, which may, under repeated loading, cause fatigue fracture of the part. Fractures in some machine parts can be avoided by these design modifications. Adapted from "Internal Stress and Fracture of Metals," *Metallurgia*, March, 1946.

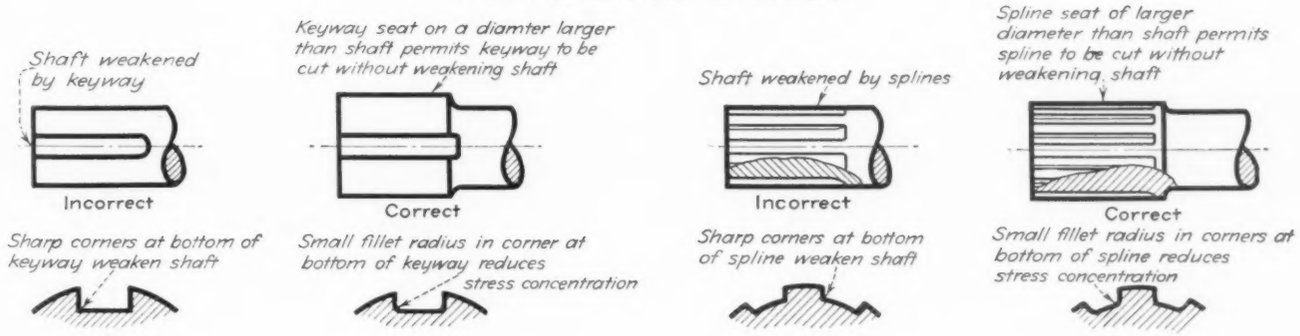
TAPERED ENDS AND COTTER HOLES


Defective form of cotter hole. Square corners permit stress concentration and reduce strength across hole
Incorrect
Rounded ends of hole give more practical shape and greater strength through hole. Holes should be cut by end mill mortising, not by drilling and filing
Correct
Slight counterboring and recessing prevents interference by burrs
Effects of drilling, chipping, and filing. Sharp corners, produced by filing, induce high local stress and become starting points of fatigue fracture
Incorrect

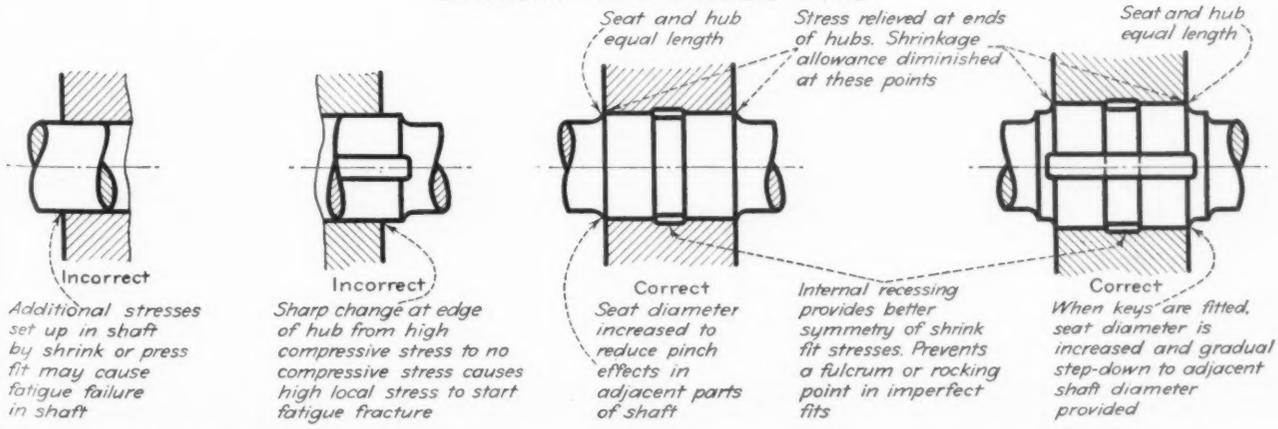
HOLES IN SHAFTS


Material around mouth of hole subjected to excessive stress. Resistance of material to fatigue failure is diminished
Incorrect
Stress relieving grooves cut on each side of hole reduce local stresses and increase fatigue resistance of shaft
Correct
Diameter of shaft enlarged around hole to reduce local stresses and increase fatigue resistance of shaft
Correct

KEYWAYS AND SPLINES


Shaft weakened by keyway
Incorrect
Sharp corners at bottom of keyway weaken shaft
Keyway seat on a diamter larger than shaft permits keyway to be cut without weakening shaft
Correct
Small fillet radius in corner at bottom of keyway reduces stress concentration
Shaft weakened by splines
Incorrect
Sharp corners at bottom of spline weaken shaft
Spline seat of larger diameter than shaft permits spline to be cut without weakening shaft
Correct
Small fillet radius in corners at bottom of spline reduces stress concentration

SHRINK AND PRESS FITS


Incorrect
Additional stresses set up in shaft by shrink or press fit may cause fatigue failure in shaft
Incorrect
Sharp change at edge of hub from high compressive stress to no compressive stress causes high local stress to start fatigue fracture
Seat and hub equal length
Stress relieved at ends of hubs. Shrinkage allowance diminished at these points
Correct
Seat diameter increased to reduce pinch effects in adjacent parts of shaft
Internal recessing provides better symmetry of shrink fit stresses. Prevents a fulcrum or rocking point in imperfect fits
Seat and hub equal length
Correct
When keys are fitted, seat diameter is increased and gradual step-down to adjacent shaft diameter provided

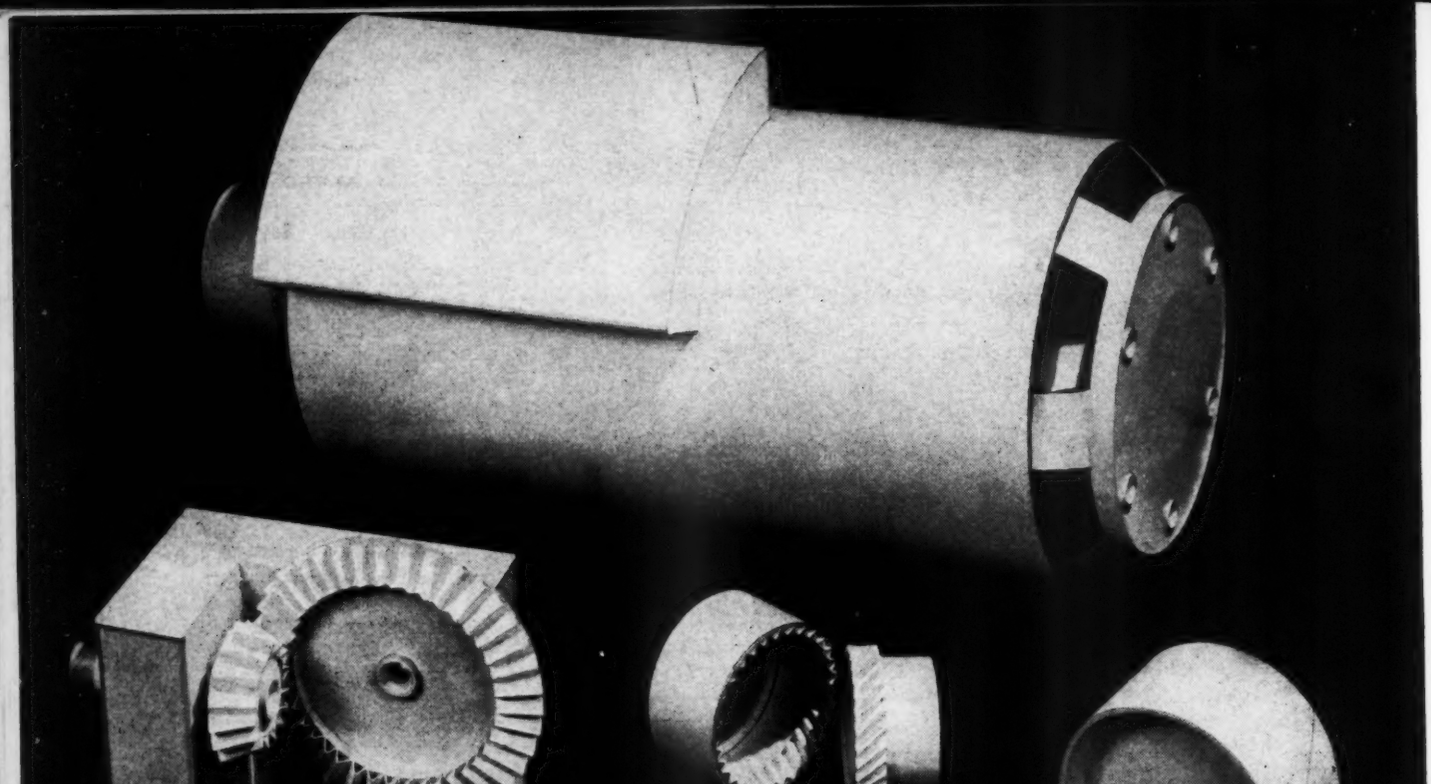


Fig. 1—Miscellaneous cardboard mock-ups. Large item is a mock-up to visualize space required over a standard aircraft engine accessory mounting pad. Mating helical splines, bevel gears, nuts and bolts all operate freely.

CARDBOARD MOCK-UPS

MORTON P. MATTHEW

Cost of materials and time have long imposed limitations on the use of mock-ups as aids in product design. Cardboard drastically reduces these limitations, and provides a medium from which accurate and detailed reproductions can be made. Methods of construction are described together with the characteristics and advantages of this often-overlooked material.

MOCK-UPS, customarily constructed from plastics, plaster, or wood, are characteristically expensive and somewhat inflexible in application. These factors, more than all others, have limited the use of mock-ups as development aids. Cardboard, however, provides an ideal medium from which mock-ups can be made and does not require a large outlay in materials and tools. Objects can be initially mocked-up from this material in the drafting office. If changes or revisions are necessary, they can be made right then and there without the difficulties and loss of time attendant with outside pattern work.

Cardboard can be cut, rolled, joined and worked to give clear-cut, accurately scaled representations of machine parts at a fraction the cost of conventional methods. Such mock-ups have rigidity and strength and can be constructed to virtually any size. They are extremely light in weight. When constructed of smooth-surfaced material, models for presentation purposes are attractive.

Box-shapes, tubes, cylinders, plates, and cones of cardboard can be readily

fashioned into spur, bevel, and helical gears, and machine elements such as wheels, splined fittings, roller bearings, nuts and bolts. Transparent lacquer, dope, or cement reduces abrasion where parts are in rubbing contact and increases the strength of the part.

A group of typical parts made from cardboard is shown in Fig. 1. The large item at the top of the photograph is a mock-up to visualize the space required over a standard aircraft engine accessory mounting pad. The model, 18 in. long and constructed of cardboard 0.024 in. thick, is accurate enough to be mounted on the studs of the actual engine, and the flange is of sufficient strength to support the body in a horizontal plane. The mating helical splines shown can be assembled in any relative position and the bevel gearing unit can be actually operated. The threads on the nuts shown can be freely turned in the bolts.

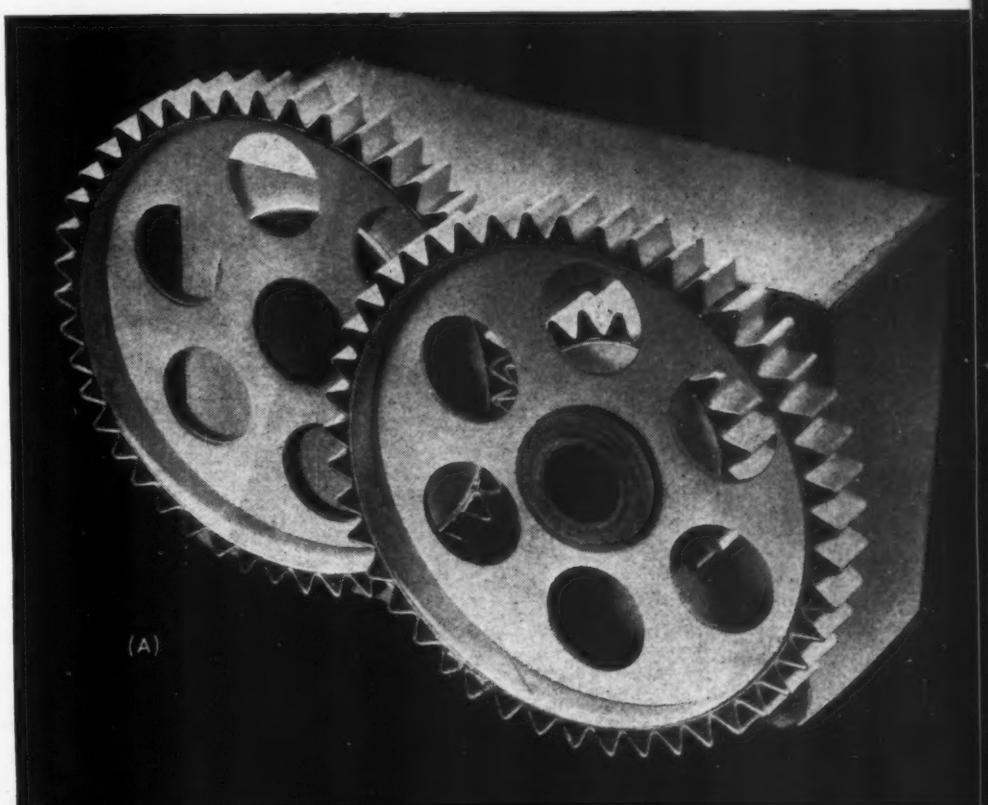
Cardboard parts can be built to assemble in exactly the same manner as a set of actual parts. To demonstrate this, an assembly of accessory drive gears in an aircraft engine is shown in Fig. 2(*A*). This same assembly is shown in Fig. 2(*B*) broken down into its various components: Gears, pinion, shaft, bearings, spacing sleeve, snap-rings, key, and nut. In this particular mock-up, the grooves for the snap-rings and the threads on the nut and shaft are omitted, but it is of decided interest to note that the rollers in the bearings are constructed of cardboard and actually rotate.

Detail and refinement to this degree are not always needed or justified in the average mock-up. It is obviously not expedient to mock-up a standard nut and bolt when these parts can be obtained from a stock bin in the shop; nor will it often be practical to mock-up a roller bearing, complete with rollers, when a simple doughnut shape of the overall bearing dimensions gives the information needed. This detail, however, is included here to demonstrate the flexibility of cardboard as a modelling medium and to show to what extent this common material can be utilized.

Parts that are too thin to be mocked-up in wood are ideally suited for cardboard. Weldments of sheet and plate can be reproduced, with the added advantage that if the interior joints in the cardboard mock-up can be reached, it is a good indication that the welds are accessible.

Gears, similar to those shown in Fig. 2, can be made that will give a positive and smooth transmission of motion and that have a definite load-carrying ability. Here again, the detail to which these items are constructed can be as simple or as complex as desired. Large involute gears, each tooth internally braced, can be constructed to aid in the study of tooth relationships; or ordinary disks can be utilized as gears in determining ratios and linkage motion. In each instance, cardboard provides the ideal medium with which to work.

In the initial stages of a product



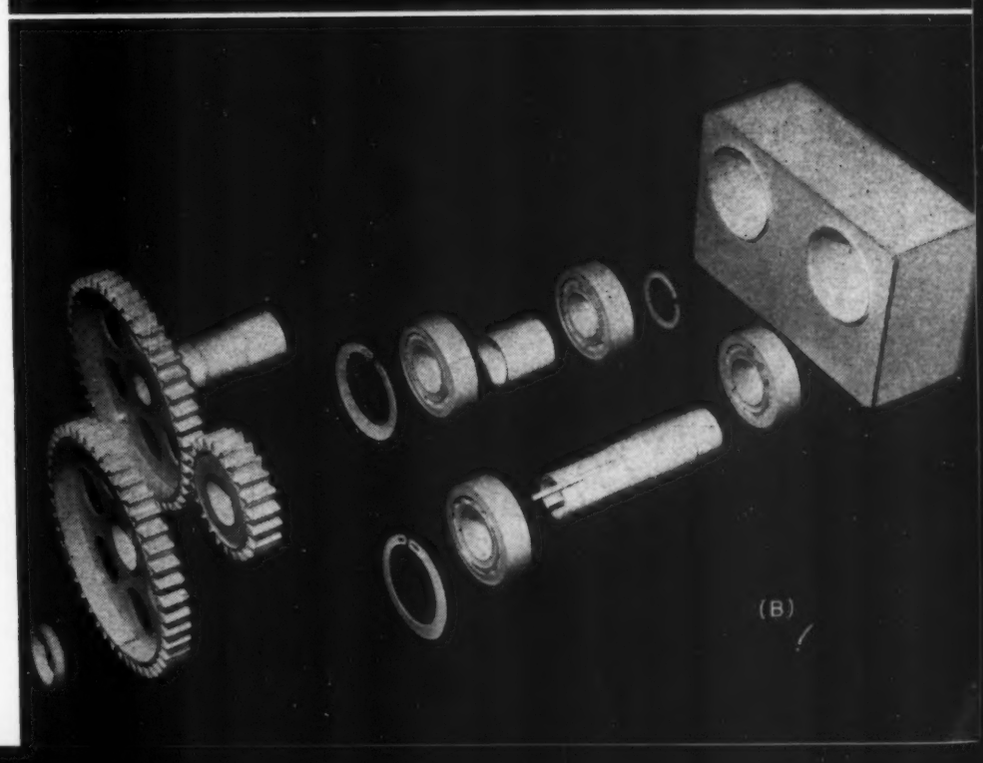


Fig. 2—(A) Cardboard mock-up of an aircraft engine accessory drive gear assembly. The gears give a positive and smooth transmission of motion and have a definite load carrying ability. (B) Assembly broken down into its components: Gears, pinion, shaft, bearings, spacing sleeve, snap-rings, key, and nut. Note rollers in bearings.

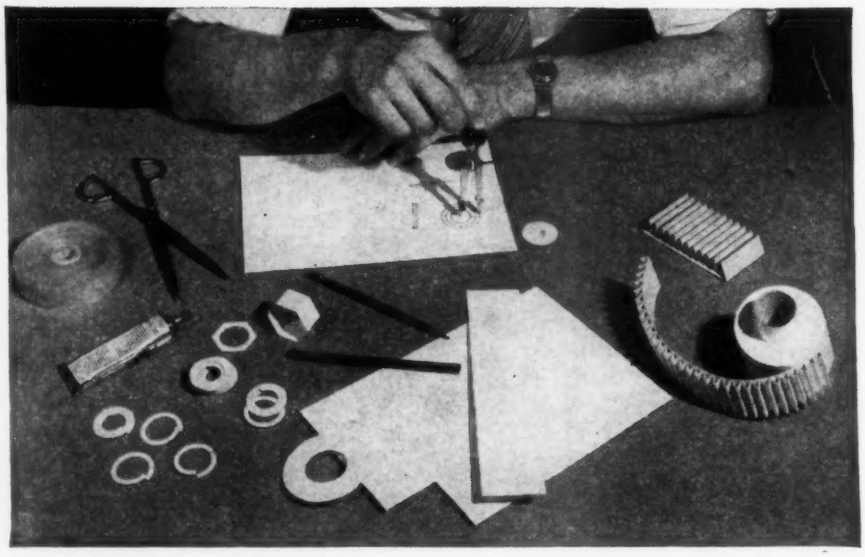


Fig 3—Construction of cardboard threads. Pieces are stacked in order and cemented to interior surface of hex-nut shell.

development, it is not necessary for the cardboard mock-up to be complete. The basic idea of the form of the machine, mocked-up from an engineering sketch will cost little and serve as an excellent springboard for additional ideas and improvements. As the design studies proceed and are put into actual drawings, a choice of further mock-up subjects can be made. These might comprise an unusually detailed part, a portion of a structure, or a determination of the clearance between two oddly-shaped parts. Mock-ups, so used, can save drafting man-hours by furnishing a clear picture of the part or item in question.

Drafting time can also be saved in the layout stages by constructing a mock-up of the basic framework of the design. This enables quick visualization, and additional design components can be readily placed. When a special study with developments and projection views is required, reference surfaces, in the form of a partial mock-up together with separate detailed mock-up parts, will save much time and confusion. For instance, a partial mock-up of a gear housing having narrow openings and a mock-up of the gears and shaft will quickly answer all questions concerning the assembly and disassembly of the unit.

Mock-ups such as these are invaluable in product development. They provide three-dimensional previews of a product from the time of its inception to its production as a marketable item. Throughout this development, the mock-ups permit a visualization of the product as a whole, and enable any potential design and manufacturing difficulties to be foreseen. Required changes in the product during development can thus be made without excessive redesign and retooling expense. Mock-ups are profitable in operation planning and tool design. The mocked-up part can be taken to the shop and actually mounted in any machine tool to ascertain clearances, fits, and machining operations. This speeds progress. The approving authorities, the engineering and sales executives, can formulate their opinions, suggestions, and approval of a project more readily when the item in question is actually seen in mock-up form. Drawings, in spite of all the elevations, isometrics, cutaways, and exploded views that can be used, are still confined to a two-dimensional plane. The third dimension must still be visualized; this requires considerable attention and effort if the drawing is complex or the viewer unfamiliar with drafting projections.

Mock-ups of complete or partial designs are particularly efficient in initiating new personnel into the intricacies of new or established products. Drawings do not always enable these newcomers to grasp the fundamentals of a specific design, nor, in accessory design, do they enable the relation of the part in question to the overall project to be fully understood. Mock-ups aid in visualizing the functional distinctions between parts or groups of parts, especially if a variety of colors are used in correlating the different sub-assemblies. Mock-ups that have been constructed to aid in the study of a particular problem will not be set aside upon the solution of that problem; rather, they will be referred to frequently for further study as the design progresses and becomes more complex.

Mock-ups are extremely useful in plant layout work, where scale reproductions of machines, conveyors, racks, and partitions are disposed around a scale floor area. From this a complete and accurate visualization of spacing and routing problems is available, and solutions are readily obtained.

Some shapes and sizes can undoubtedly be made more readily or less expensively from materials other than cardboard. Double curvature surfaces, for instance, cannot be readily constructed of cardboard and are best reproduced in plaster. But combinations of mock-up materials can often be made so that the overall advantages of cardboard are retained.

* * * *

In 1819, a Danish scientist, Hans Christian Oersted, while lecturing to his classes carried a wire charged with current over a compass needle and parallel to it. He found that this caused the needle to turn sharply from north to the east. This showed the close relation between magnetism and electricity, a fact which other scientists had suspected but none had been able to prove.

* * * *

The poppet valve steam engine with one eccentric to open and close the four valves, was first used by Robert L. Stevens in 1828 on the steamboat *New Philadelphia*. In 1841, Francis Bowes Stevens, a nephew of Robert L., patented an improvement of this by which two eccentrics instead of one were used that enabled the two steam valves to be opened and closed independently of the exhausts.

ELECTRICAL INDICATING INSTRUMENTS

L. F. PARACHINI
Engineer, Weston Electrical Instrument Corporation

Fundamental mechanisms, operating characteristics, and range of functional uses of generally used electrical indicating instruments. Discussion includes moving iron, electrodynamometer, and permanent magnet moving coil types, plus guidance on using common accessories such as shunts, instrument transformers, dry rectifiers and thermocouples.

THE PRINCIPLES used in electrical indicating instruments are the basis of much of the measurement technique in industry. This discussion will be confined to the fundamental mechanisms and characteristics of indicating instruments and some accessory devices.

Indicating instruments translate an electrical force into a mechanical force, as is done in an electric motor, and this force is opposed by a precisely calibrated force, such as a spring. The point at which these two forces balance, can be translated to show such quantities as amperes, volts, watts, r.p.m., foot candles, or minutes of curing time in a press. Measurement can be made for anything where a finite electrical force can be developed in terms of the measurement to be made.

Three Basic Elements

The three most important mechanisms used for indicating instruments are the: Moving iron, electrodynamometer, and the permanent magnet moving coil, or D'Arsonval. Although some other types are also used, such as induction, polarized iron vane, and electrostatic, relatively they are of secondary importance in industrial applications. Each of the mechanisms are current sensitive devices, operating by virtue of a current passing through them and producing a magnetic field that acts on iron or other magnetic fields to produce motion. In general, the current produces a proportional force that works against a carefully calibrated spiral spring or set of springs. The point of equilibrium of the two forces is then read on the scale.

Both in the design and the use of instruments, operating conditions must be considered to obaain long life and reliable results. For example, changes in temperature, vibration, shock, humidity, frequency (for a.c. measurements), extraneous magnetic fields, and many other conditions either acting singly or in combination must be considered.

Because instrument terms are sometimes used loosely, it may be helpful to explain exactly what is meant by instrument proper, instrument, mechanism, moving element, and accessory as they are used in this discussion.

INSTRUMENT PROPER, is the mechanism and the scale built into the case including all devices, such as resistors and shunts, that are built into the case or are nonremovably attached.

INSTRUMENT, includes not only the instrument proper, but all necessary accessories such as shunts, shunt leads, resistors, reactors, condensers and instrument transformers.

MECHANISM, includes all essential parts for producing and controlling the motion of the reading indicator. It does not include the base, cover, scale, or any such part as series resistors or shunts used to adjust the indicated value of the measured quantity to agree with the actual value.

MOVING ELEMENT, includes all parts that move with the pointer.

ACCESSORY, in its broadest sense, includes all devices such as shunts, resistors, and rectifiers used either internally or externally to convert a basic mechanism for measurement of quantities other than that for which it is inherently capable.

The data on typical mechanisms and their application with various accessories to the more common measuring jobs are given in tabular form for convenience of use. Brief statements of principles involved, basic construction details and an indication of the extent of utility for normal instruments are included. Although special designs, such as vacuum tube voltmeters, have an increasing field of usefulness they will not be included in this presentation.

MOVING IRON OR REPULSION TYPE

OPERATION: Current flowing through field coil winding creates magnetic field that magnetizes soft iron pieces inside coil. The magnetized pieces of iron have similar poles adjacent thus creating a repelling force between them. Free one rotates about a pivoted point. Angular deflection of pointer stops at the point of equilibrium between the actuating force and the restoring force of spiral spring.

CONSTRUCTION: Field coil wound of copper wire, size and turns varying with range and type of instrument.

Iron pieces usually small in cross section and of a high permeability material, such as 4 percent silicon steel transformer iron. Shape of iron pieces and location in magnetic field chosen to produce most desirable scale distribution. Relative shape of concentric vane iron pieces provide many special scale characteristics.

Moving element staff is double pivoted with hardened conical pointed steel pivots turning in V cavity jewels.

Single spiral spring is not part of the electrical circuit.

Damping of pointer oscillation for rapid indications obtained by aluminum vane moving in a tight fitting air chamber.

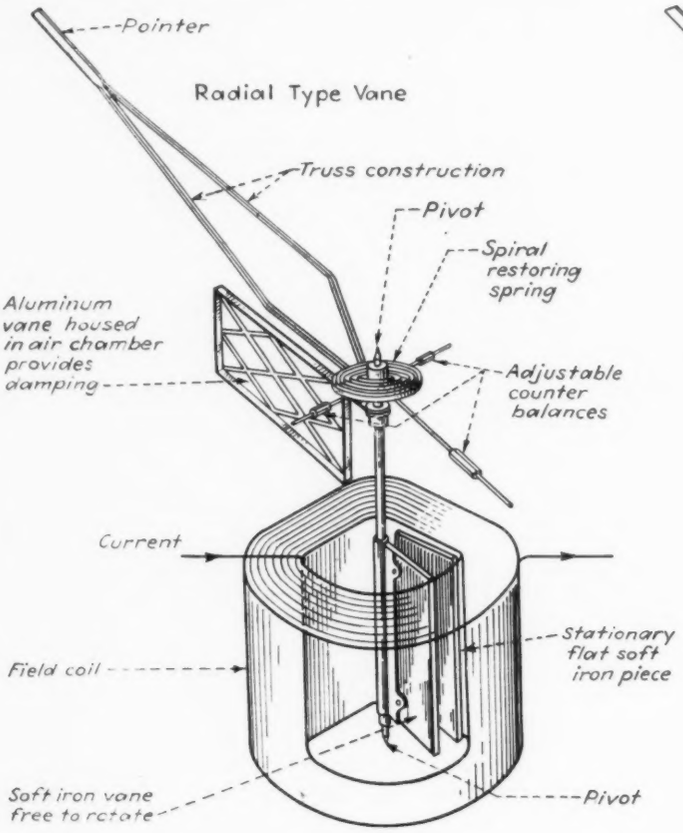
USE: Current measurement: As current mechanism only, without accessories, is suitable for a.c. current measurement for frequencies up to several thousand cycles. D.c. current measurement possible, but less accurate and desirable. Limits: 0.005

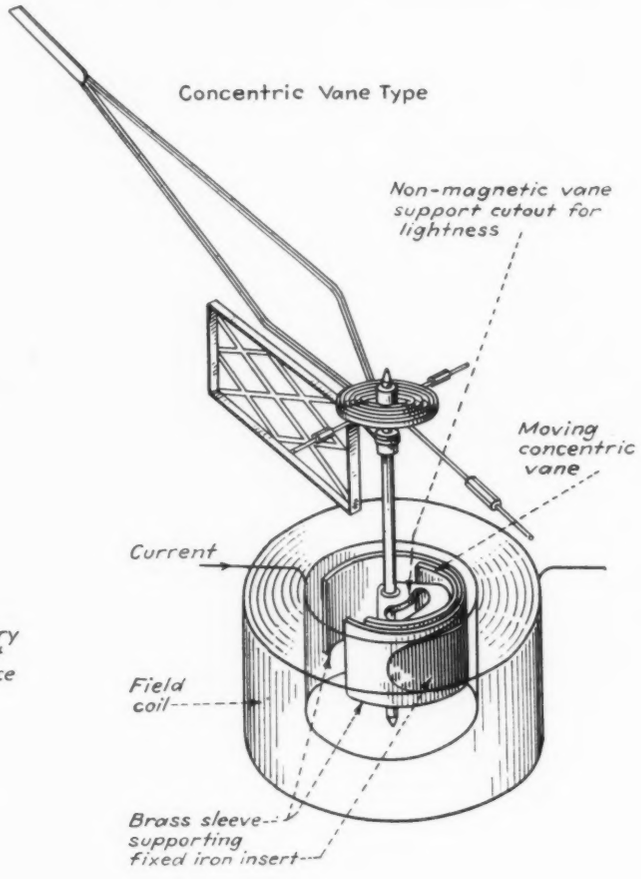
to 500 amp., considering all sizes of instruments and mechanisms.

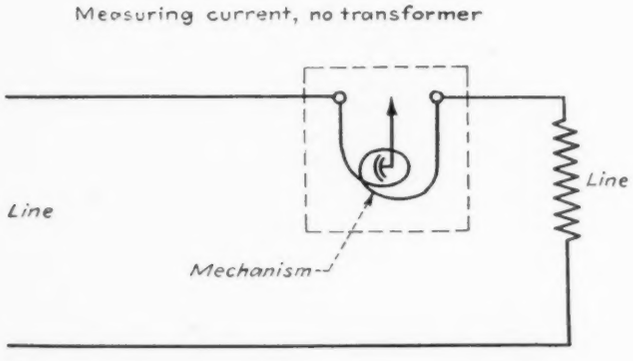
Mechanism plus current transformer: A.c. current measurement limited by transformer; approximately up to 12,000 amp. Multi-range instrument possible by use of current transformer.

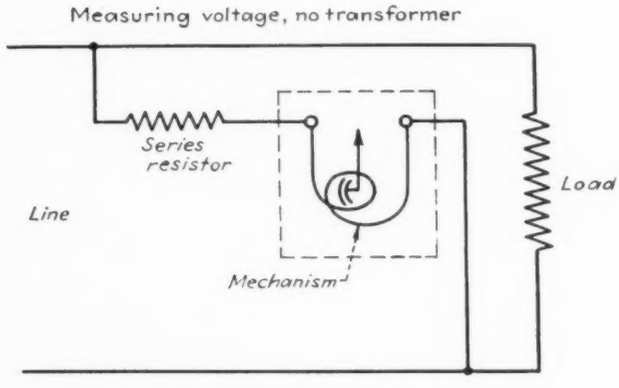
Voltage measurement: Mechanism with series resistance suitable for a.c. voltage measurements up to a frequency of approximately 3,000 cycles, with special compensation. Limits: 1 to 3,000 volts approximately depending on size and type of instrument. Normal practical limit, 750 volts with resistor. For higher ranges it is best to use potential transformers. More than one range can be obtained by tapping off on resistor unit; combination must be properly chosen based on factors affecting accuracy.

Mechanism with series resistor and potential transformer: A.c. voltage measurements up to 160 kv. possible on switchboard installation; up to approximately 10 kv. for portable use.









ELECTRODYNAMOMETER TYPE

OPERATION: Current flowing through the fixed coil windings and moving coil winding produce magnetic fields that react on one another. Moving coil torque is a function of the product of the two magnetic fields; thus in phase components of the two currents, through fixed coils and through moving coil. Angular deflection of the coil is opposed by the torque of a pair of spiral springs.

Where two elements on one shaft are used, such as in the polyphase wattmeter, the total developed torque is the sum of the individual torques.

For the crossed coil type of movement the developed torque is a function of the resultant moving coil currents and the field coil current, considering both magnitude and phase. This type of mechanism essentially operates on the ratio of currents in the moving coils.

CONSTRUCTION: All coil windings of copper wire. Size and number of turns a function of the range and type of instrument. Moving coils usually of small wire to keep weight as low as possible.

Fixed coils rigidly supported to prevent shift in use.

Shaft double pivoted and jeweled similar to that of moving iron mechanism. Damping is by air vanes.

Springs: Two per element, usually of equal strength. Springs serve as conductors of moving coil current as well as providing opposing force.

Crossed coil type movement has 3 or 4 filaments instead of springs. Filaments act as conductors only, and are designed not to influence the deflection of the coil system.

USE: Single Element. Current Measurements: Single element mechanism only is suitable for current measurements either d.c. or a.c. at frequencies up to several thousand cycles. Fixed and moving coil connected in series.

Limits: 0.010 to 0.5 amp. considering all sizes of instruments and mechanisms.

By the use of a special resistor, used as a shunt across the moving coil, current up to 30 amp. can be measured.

Voltage Measurement: Fixed coils and moving coil in series, and they in turn connected in series with a resistor make a voltmeter.

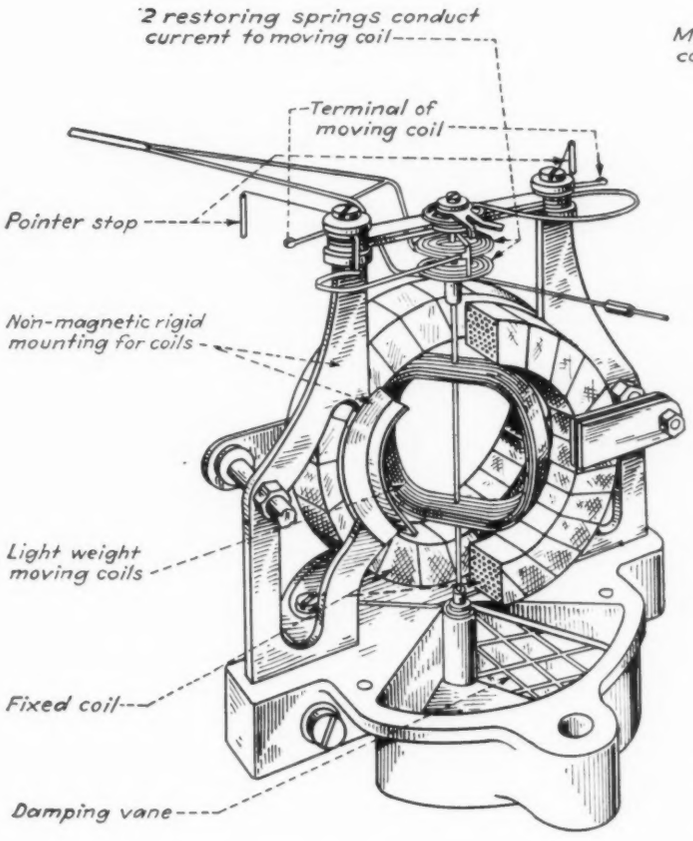
Limits: 1 to 750 volts approximately considering all sizes and types of dynamometer instruments. More than one range is possible by tapping resistor. Combinations must be carefully selected for proper operation.

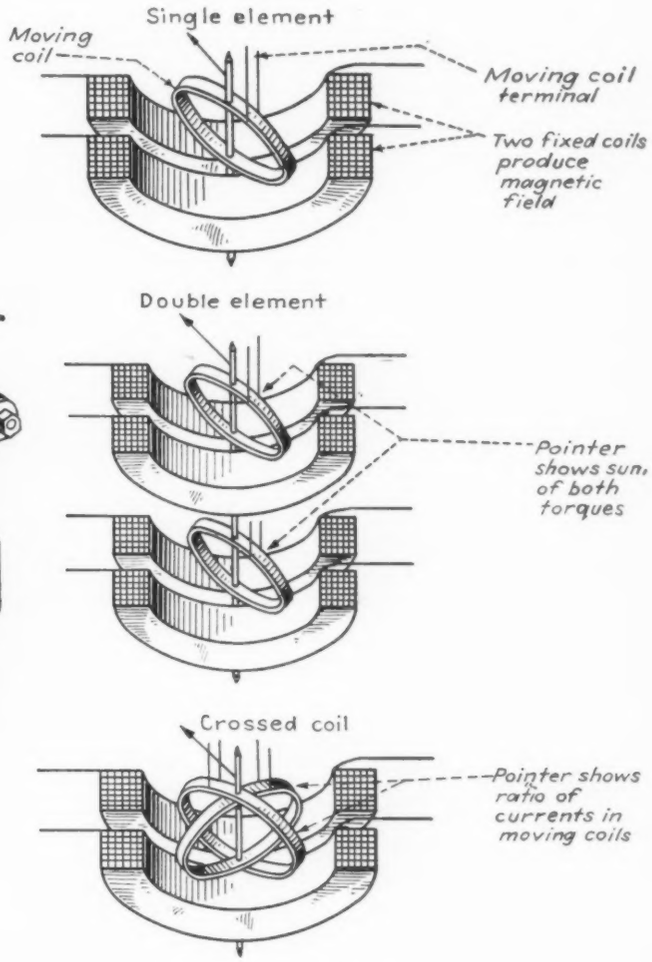
Power Measurements: The product of current and voltage in phase is indicated by this type of mechanism. Line current is passed through the fixed coils and a current in terms of the line voltage passed through the moving coil with a series resistor. Only in phase, components produce torque by virtue of the characteristics of magnetic fields. Also, d.c. watts can be indicated.

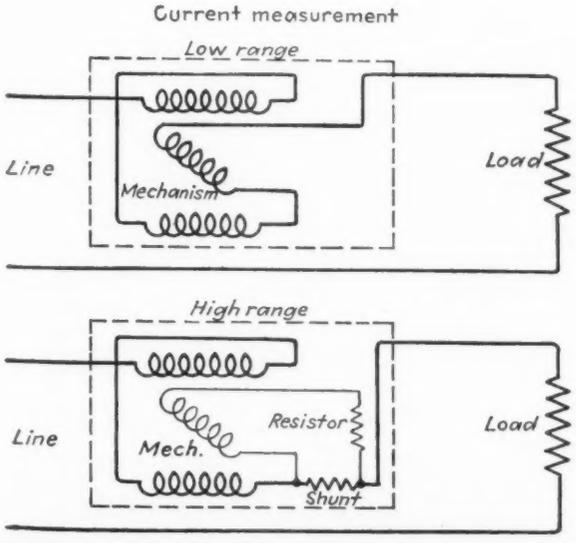
Considering all types and sizes of instruments and mechanisms, general limits are: Current circuit, 0.025 to 50 amp. Voltage circuit, 5 to 500 volts.

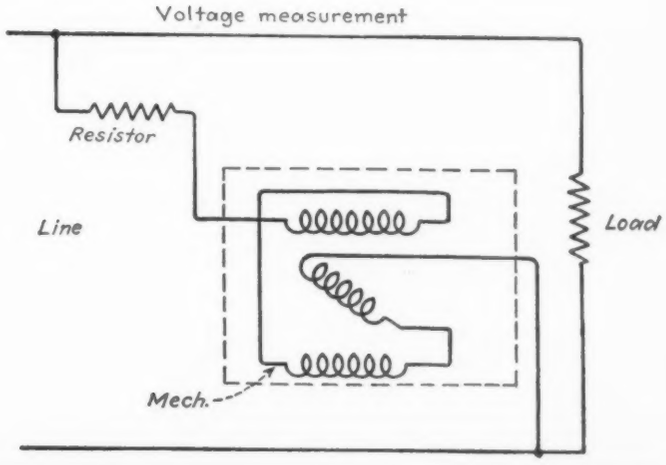
Two Element Mechanism for power measurements. Application similar to the single element type, except used in polyphase a.c. circuits, or d.c. circuits of more than two wires.
Not normally used for other measurements.

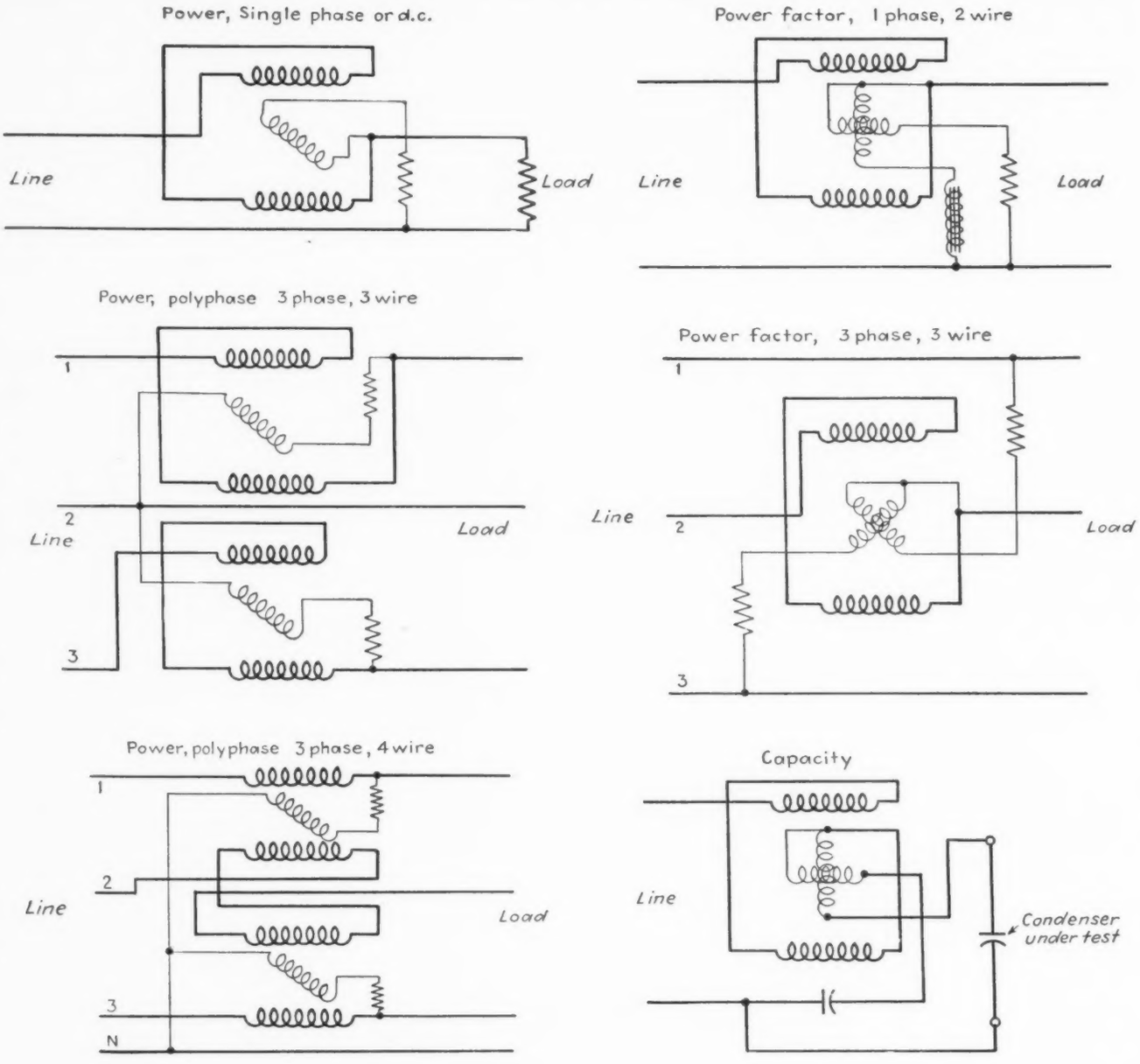
Crossed Coil Mechanism. Power factor measurement, or phase angle, as well as such measurements as of capacity, and frequency, possible with this ratio mechanism. Relatively complex connections.











PERMANENT MAGNET MOVING COIL, OR D'ARSONVAL TYPE

OPERATION: Current flowing through a coil free to rotate produces a magnetic flux that reacts on a magnetic field produced by a permanent magnet. Moving coil torque is a function of the field strength of the permanent magnet and of the field strength produced by the current in the moving coil. Angular deflection of the coil balanced by two spiral springs.

CONSTRUCTION: Moving coil, rectangular in shape, wound of copper or aluminum wire is assembled in a short air gap of a permanent magnet circuit. Number of turns and size of wire used depends on requirements. Wire sizes as small as No. 50 copper, 0.001 in. dia., are used.

Moving coil wire normally wound on a metallic frame, thus providing a short circuited conductor that produces eddy currents and damps the pointer oscillation. Damping characteristics controlled by use of various thicknesses of frames and by use of materials such as brass, copper, and aluminum.

Hardened steel pivots and jewel bearings used.

Permanent magnets of tungsten steel, cobalt steel, and Alnico, provide specific characteristics.

Accurate core and pole piece assembly insures permanence of uniform flux distribution.

Special scale characteristics can be obtained by specially shaped pole pieces to alter flux pattern in the air gap.

Mechanisms can be made extremely sensitive and thus adaptable to many special measurements.

USE: For d.c. current: Mechanisms alone, without accessories, measures d.c. current only.

Limits: 0.000 005 to 0.030 amp., considering all types of this instrument.

Mechanism with shunt. Shunt used for currents above 0.030 amp. Limit of measurement only that of application (60,000 amp. at present). Multi-range combinations possible with shunt accessory.

D.c. voltage: Mechanism in series with a series resistor applicable to the measurement of potential between two points in a circuit.

Limits: 0.001 to 20,000 volts considering all types of this instrument. Single or multi-range combinations possible.

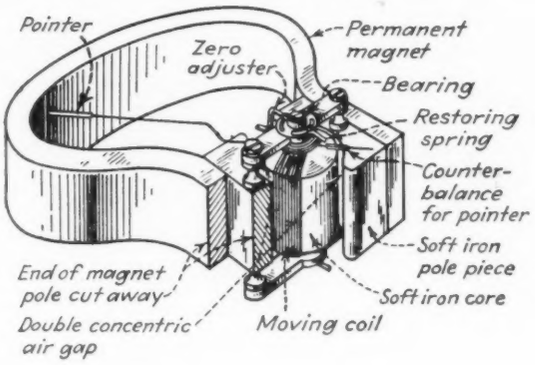
A.c. current: Frequencies beyond 20,000 cycles. The d.c. mechanism combined with a thermocouple can measure high frequency current. Current measurements up to 300 megacycles are possible.

Limits: 0.0015 to 200 amp.

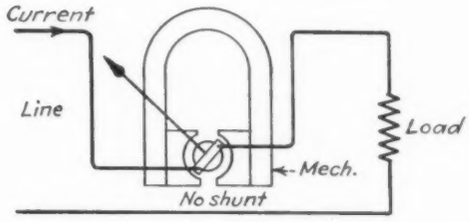
A.c. current or voltage: Frequencies up to approximately 20,000 cycles. By the use of a copper oxide rectifier in conjunction with this mechanism, alternating current measurements of voltage and current can be made.

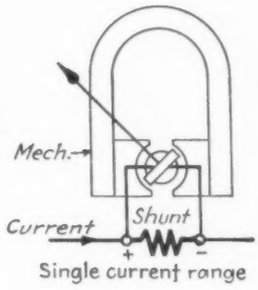
Limits: Current, 0.000 05 to 0.005 amp. with small rectifier. Voltage, 1 to 20,000 volts.

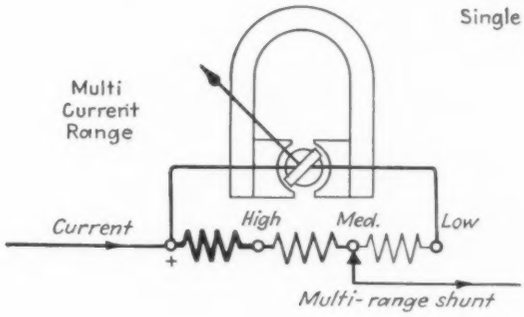
Because of the many accessories for this mechanism, it has a wide range of usefulness.



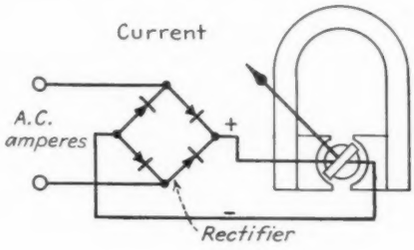
Direct Current Measurement

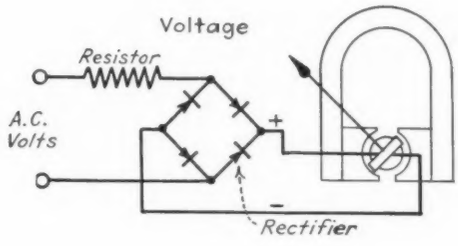




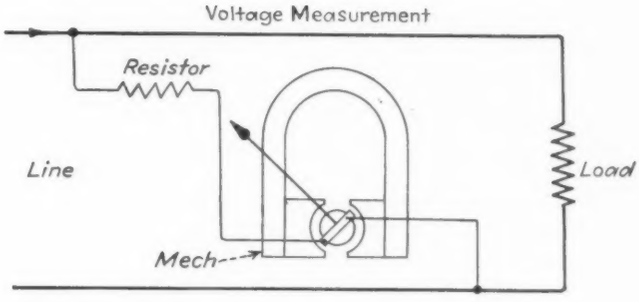


Alternating Current Measurement

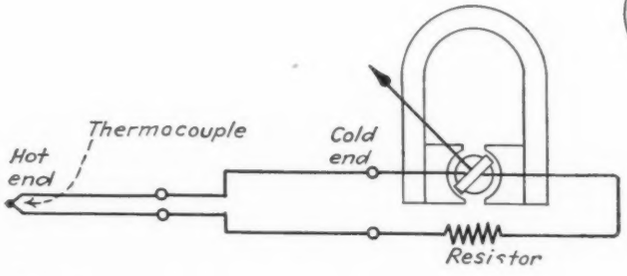


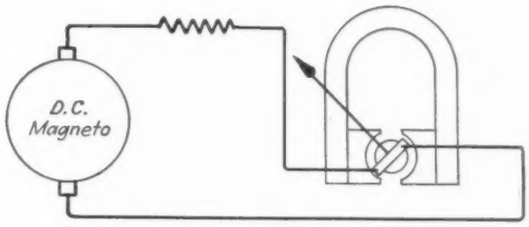


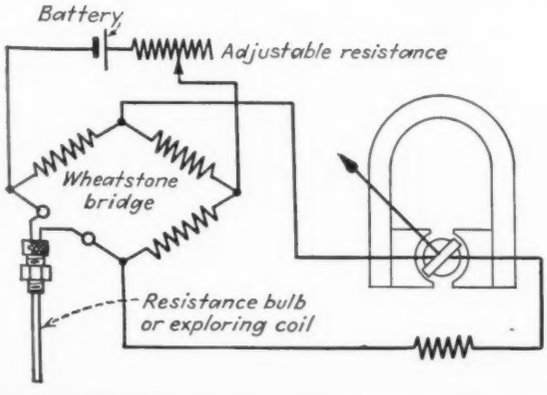
Voltage Measurement

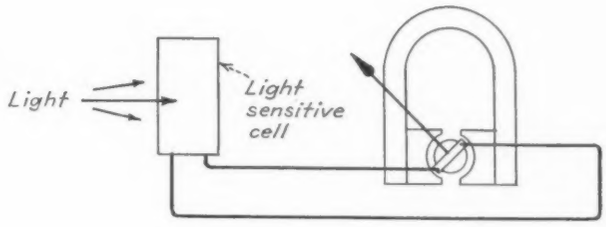


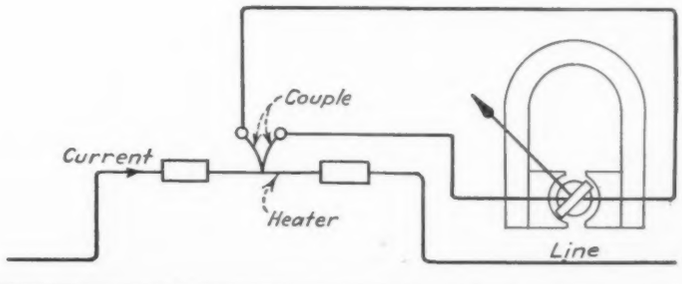
Connection Diagrams











SHUNT

Accessories

Shunts are used to measure d.c. current beyond the ability of a permanent magnet moving coil mechanism. In addition, a shunt permits: (1) Construction of more than one range instruments by use of ring shunt; (2) mounting of instrument at some point remote from power conductor; and (3) use of more than one instrument on one conductor with a single shunt, thus providing economical multiple indications.

OPERATION: A shunt is a particular type of resistor connected in parallel with a measuring device to extend its current range. Its resistance is so proportioned to the resistance of the mechanisms that the major portion of the current to be measured passes through the shunt and a small proportional amount passes through the moving coil of the instrument.

Shunt resistance normally adjusted to give a voltage drop of 0.05 or 0.10 volt, at rated full load current. Mechanism circuit in turn is adjusted to this voltage at its rated full scale current by means of a series resistor.

Low voltage drop (0.05 or 0.10 volt) keeps power dissipation low; permits minimum size and weight, and produces minimum insertion effect on circuit being measured.

CONSTRUCTION: Thin blades of Manganin alloy are soldered into large copper or brass blocks. Separate connections for line and for instrument insure against errors of indication caused by current distribution in the blocks.

Manganin alloy used because of its high specific resistance and its negligible temperature coefficient, change of resistance with temperature.

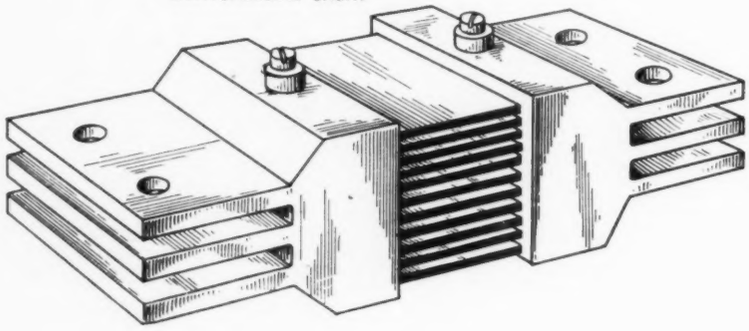
Shunt designed to operate at temperature well below the softening point of solder.

Shunts external to the instrument are provided with leads as part of the circuit; normal length is 8 ft.

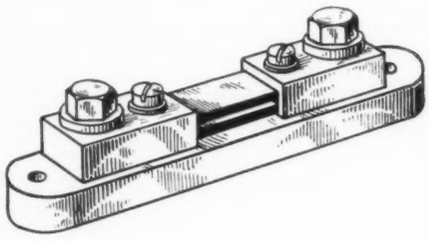
USE: For d.c. current measurements more than approximately 0.030 amp. In general, used internally up to 50 amp. in small instruments and up to 500 amp. in special portable ones. Normally, more than 50 amp., shunts are external.

In use, these factors are important: (1) Mounting should provide maximum heat dissipating ability; (2) adequate conductors tightly fastened must be used; (3) leads between instruments and shunts must not be altered; (4) external shunts less than 25 amp. must be adjusted to their instruments.

Switchboard shunt



Portable shunt



SERIES RESISTOR OR MULTIPLIER

Accessories

Series resistors extend the use of either an a.c. or d.c. current sensitive mechanism to the application of measuring voltage between two points in a circuit.

They control the current flow in a mechanism in terms of voltage for potential circuits of wattmeters, power factor meters, and the like.

External units allow measurement of higher voltage than is readily applicable to the instrument proper.

OPERATION: A series resistor or multiplier is connected in series with a mechanism, or portion of a mechanism, to limit the current flowing in proportion to the voltage applied.

Total resistance of a resistor depends on the current requirement of the mechanism at the voltage involved. D.c. mechanisms usually require low current, while the relative inefficiency of the moving iron or dynamometer requires more current.

Proper proportioning of series resistance to mechanism resistance is necessary for good design. This limits the voltage range of many instruments, particularly a.c. instruments. All voltmeters and potential sensitive circuits designed for minimum insertion effect commensurate with other considerations of use.

CONSTRUCTION: Series resistors or multipliers are made in various forms such as air coils, spools, and resistor cards. Wire used is of high specific resistance having low or negligible temperature coefficient. Materials such as Manganin, constantan and Nichrome are used depending on total resistance required per spool, sheet, or coil.

Spool units usually wound to 500,000 ohms to dissipate about 1 watt, depending on size. They are wound non-inductive for low frequency, up to 20,000 cycles.

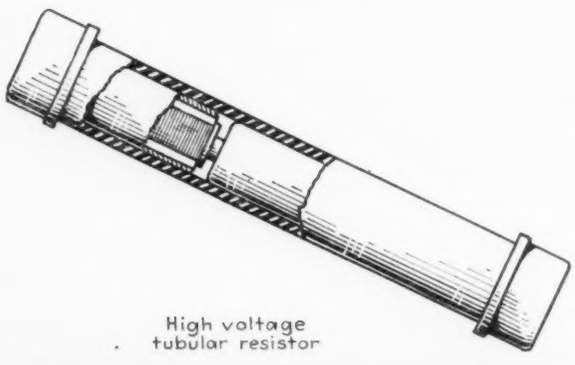
Sheet and card resistors are wound to 15,000 ohms maximum and to dissipate a maximum power of approximately 3.5 watts. Are inherently non-inductive although not normally used beyond 50,000 cycles.

Protective coating of varnish or wax or both used.

USE: For all d.c. and a.c. voltage measurements, or for the conversion of a current sensitive instrument mechanism to voltage function

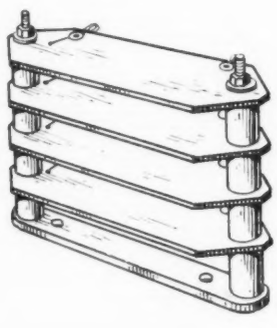
D.c. measurements of voltage at current requirements of 0.000 05 amp. (50 microamperes) are practical. For a.c., currents of the order of 0.006 amp. are a minimum. Spool resistors normally used for d.c.; sheets for a.c. because of greater power dissipation requirement.

In use, these factors are important: (1) Mounting should provide maximum heat dissipating ability, and maximum leakage resistance path; (2) should provide adequate voltage protection to ground, (3) external resistors should be matched with instrument, especially for a.c. measurements where each is individually adjusted; (4) wire used for connections must have adequate insulation; size not important; (5) when using external unit, instrument proper should be in grounded on low voltage side.



High voltage tubular resistor

Wire wound spool resistor



Card type resistor

CURRENT TRANSFORMER

Accessories

Current transformers are only an a.c. current sensitive device. Used to: (1) Increase the range of an instrument; (2) permit measurement of high currents beyond the practicability of a self-contained device; (3) permit flexible installation, such as providing for constant circuit conditions even after removing indicator; (4) insulate instrument from high voltage; and (5) permit use of more than one unit per transformer.

OPERATION: The primary winding of a current transformer is connected into the line to be measured in series with the load. No appreciable voltage exists between the two terminals and the primary current is not determined by the load on the secondary, or instrument side. Thus a current proportional to the load current can be impressed through the instrument.

The secondary of most current transformers is wound for 5 amp. at rated primary current. More than one mechanism can be connected to the winding.

Current transformer design seeks a truly proportional current at 180 deg. out of phase with line current. Deviation is caused by factors such as size and material of core, magnetizing ampere turns, load on secondary, and frequency.

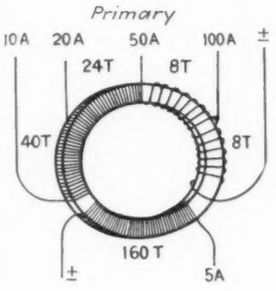
CONSTRUCTION: Current transformers are usually made with ring cores having no air gap operating at low flux density. Material such as 4 percent silicon steel, Hypernik, and Mumetal is used.

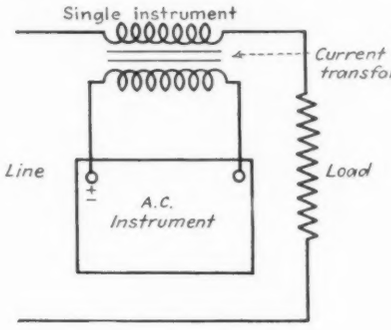
Wound primaries up to 100 amp. are common; for greater ranges, the line conductor is passed through the core hole.

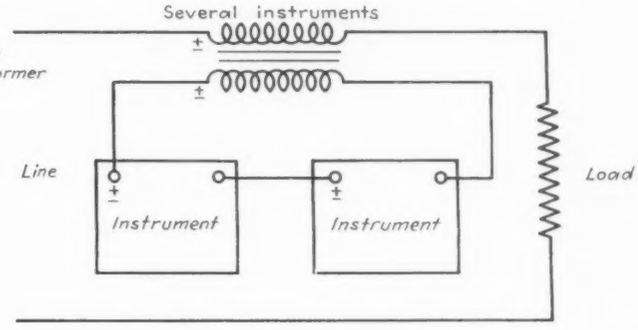
Secondary windings use short circuiting switches to close the current winding before an instrument is removed, to prevent high induced voltage.

Adequate voltage protection between primary and secondary windings isolates the instrument proper.

USE: Most current transformers are used external to the instrument proper. In general, in a.c. measurements it is economical to use transformers for currents greater than 10 amp. since more than one instrument is normally involved.







POTENTIAL TRANSFORMER

Accessories

Potential transformers used only on a.c. with a.c. voltmeter, mechanism and series resistor; or a.c. voltage sensitive circuits, such as potential circuit of wattmeter. Potential transformers: (1) Extend range of voltmeter, (2) measure high voltage not safely applied to instrument proper, (3) can supply several instruments, and (4) instrument can be remote from circuit being measured.

OPERATION: Transformer is similar to a power transformer, except that in a potential transformer the secondary current is of the same order as the magnetizing current.

Connects across the line and ideally provides a voltage in true proportion to the primary but 180 deg. out of phase. Variations from this ideal are caused by same factors as affect current transformers.

Most potential transformers have 115 volt secondary at rated primary voltage.

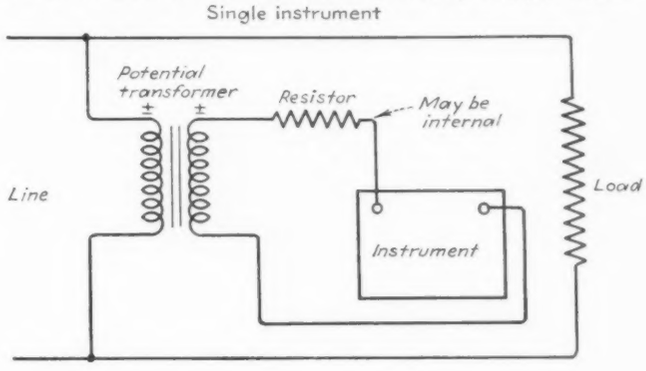
CONSTRUCTION: Core usually of 4 percent silicon transformer iron operated at low flux density, and of the core or shell type.

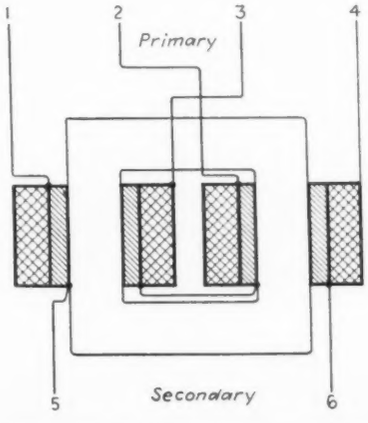
Windings of primary and secondary are close together to reduce leakage reactance; resistance is as low as possible.

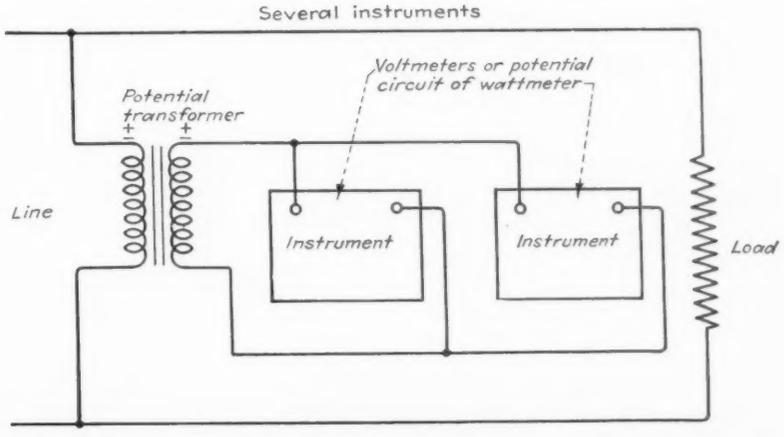
Adequate insulation provided between primary and secondary to protect instrument and operators.

USE: Most potential transformers used external to instrument. Normally used to extend voltmeter ranges beyond 750 volts; or used where more than one instrument is connected, as in power measurements involving voltmeters, wattmeters, and power factor meters.

Measurement up to 160 kv. possible by special switchboard units. Portable transformers normally used up to 10,000 volts.







COPPER OXIDE RECTIFIER

Accessories

Copper oxide rectifiers make possible the use of a sensitive low energy d.c. mechanism for the measurement of a.c. current and voltage (with series resistor) whenever the power requirements of the moving iron and dynamometer are excessive for the circuit. In general, a rectifier type instrument is approximately fifty times more sensitive than a dynamometer or a moving iron type.

For measurements of current and voltage in the audio frequency band that are not practical with the two a.c. mechanisms.

OPERATION: Copper oxide disks form virtually one way valves for current flow. Thus rectified a.c. can be used to operate a d.c. mechanism.

Four disks arranged in bridge fashion are ordinarily used; single disks and special bridge arrangements can be applied for special purposes.

Mechanisms with rectifier respond to the average value of the rectified current; however, the combination is usually calibrated in terms of root mean square of a sine wave.

Effective resistance of a rectifier increases with decrease in current resulting in high impedance at low currents. For best results, resistance of mechanism must be chosen to match this impedance and other factors, such as temperature and frequency, must be carefully considered.

CONSTRUCTION: Rectifier element composed of a thin film of oxide of copper, formed by an appropriate heat-treatment on the surface of a small copper disks.

Several disk sizes used in order to maintain best characteristics for given application.

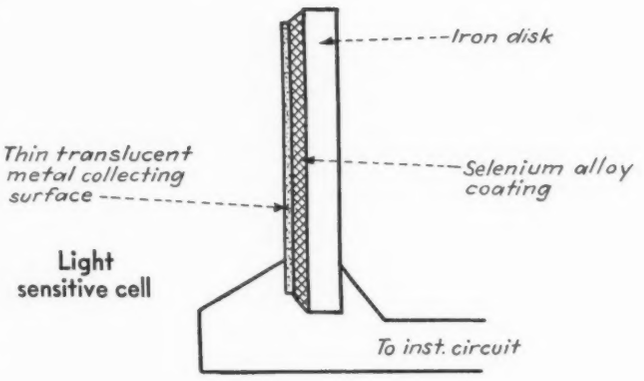
Pure gold is cathode sputtered on the surface of the oxide and copper for good contact.

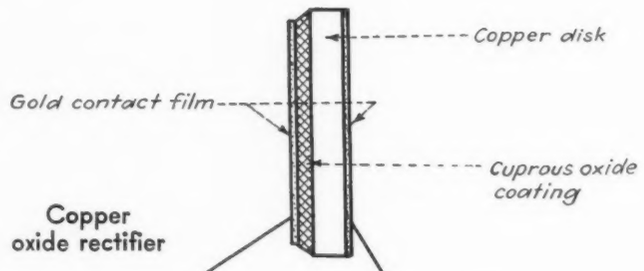
Disks hermetically sealed in plastic housings to insure constant performance with time. Copper leads of sufficient length are used to insure against damaging the oxide coating when soldering.

Assembly small enough to be mounted in smallest 2½ in. panel instrument.

USE: For a.c. current and voltage measurements where power available for instrument is limited. High voltmeter sensitivities (low current) much beyond scope of other a.c. instruments are practical.

Accuracy of use not equal to that of other types of a.c. instruments because of the effects of wave form, temperature, and frequency.





THERMOELEMENTS

Accessories

Thermal elements make possible the use of sensitive low energy d.c. mechanisms for the measurement of a.c. current of frequencies up to 100 megacycles at good accuracy, and to 300 megacycles with fair accuracy. Usable at lower frequencies with greater accuracy than is possible with rectifier type.

OPERATION: The heating effect of a current passing through a conductor is used to raise the temperature of a junction of two dissimilar metals, the cold end of which is connected to a d.c. mechanism. Heat is a function of the square of the current and the resistance of conductor (heater) that in turn is translated to a voltage across the cold ends of the couple (two dissimilar metals). Indication is thus a function of I^2, producing a squared scale characteristic, provided cold end of the couple is not affected materially. In compensated type elements special provision is made for this factor.

Couple voltage not affected by frequency except as it changes the effective a.c. resistance and thus the heat for a given current.

CONSTUCTION: Vacuum Couple. Fine wire single heater and couple assembly inclosed in a highly evacuated vacuum glass bulb having a pressure of less than 0.000 01 millimeter of mercury. Heater materials such as carbon and special platinum alloys used. Couples consist of such combinations as Plat-10 percent iridium and constantan. Couples generate 5 millivolts on open circuit at rated heater current.

Bridge Couple. An arrangement of a series of couples disposed in bridge fashion and mounted on a plastic plate. Usual unit consists of three platinum alloy, constantan couples per arm of bridge, making 12 total. Open circuit voltage developed of the order of 10 millivolts at rated current. Resistance of bridge arms is carefully balanced to eliminate a.c. potential at the d.c. terminals, which would vibrate mechanism pointer.

Compensated type. Couple is compensated for cold-end temperature changes by bringing back the couple ends in thermal contact with the relatively massive blocks that terminate the heater. Thus, the ends of the heater and couple are at the same temperature. Special copper strips are used as the cold end couple conductors; they are in thermal contact with the blocks, but electrically insulated by thin sheets of mica. Heater usually of tubular construction to reduce skin effect at high frequency. Connections for the couple to mechanism are made to form as small a loop as possible in order to eliminate induced currents. Low loss plastic used where necessary. Unit generates approximately 12 millivolts open circuit at rated current.

USE: Principal use is for measurement of high frequency a.c. currents, using a d.c. permanent magnet moving coil mechanism as the indicating unit. Various ranges and uses follow.

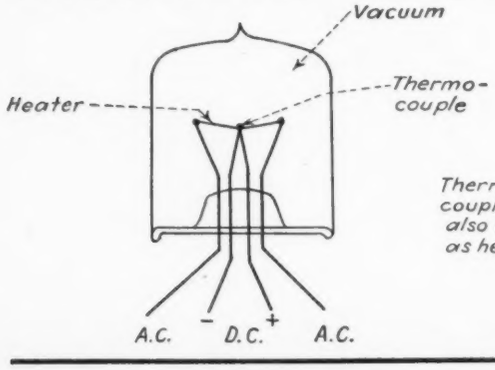
Vacuum type: 1 to approximately 150 milliampere; with ranges up to 500 ma. practical for special applications.

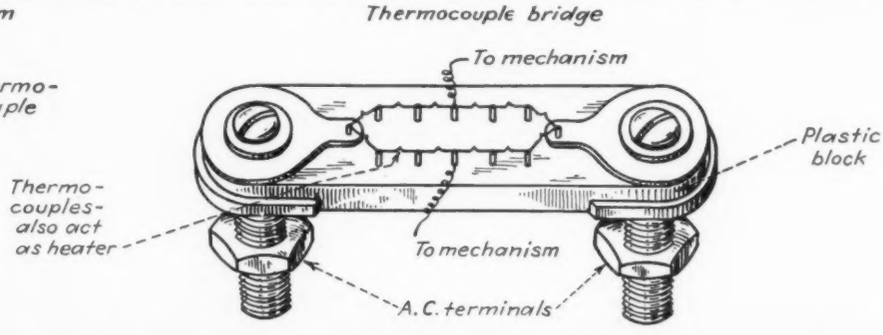
Bridge type: 100 to 750 ma.

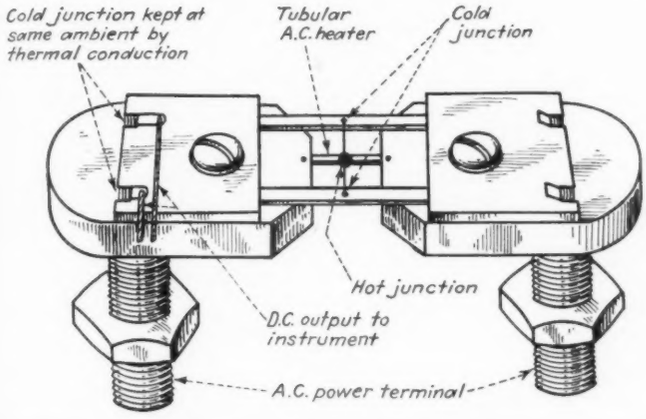
Compensated type: 500 ma. to more than 50 amp.

Voltage measurements are possible by using vacuum couple or bridge type with series resistor in a.c. side. Frequency coverage limited by type of resistor used; normal span up to 15,000 cycles.

In general, thermocouple instruments are limited in overload to approximately 50 percent because the heat developed is a function of the square of the current and because heater conductors are made small in diameter to give high speed response.







Other Accessories

Each of the following four accessories is used with a d.c. permanent magnet moving coil mechanism to measure respectively. (1) Light intensity; (2) temperature by thermocouple or resistor bulb; and (3) rotational speed by magneto.

LIGHT SENSITIVE CELL

OPERATION: A converter of light energy to electrical energy. It is a self generating "solid" or so called "barrier layer" type of cell. Current output is a function of the illumination on the cell surface and the resistance of the external instrument circuit. Ideal condition is with zero external resistance resulting in linear response of output to illumination. Sufficient current produced at normal illumination to operate d.c. mechanism without amplifers or auxiliary devices. No separate source of energy required

CONSTRUCTION: An iron disk on which is formed a selenium oxide coating protected by a transparent metal coating. Disk sealed into a plastic housing for protection against moisture. Terminals provided for connection to external circuit. Filters of various characteristics are used to influence cell output in terms of special conditions.

RESISTANCE BULB OR EXPLORING COIL

OPERATION: Measures temperatures by Wheatstone Bridge circuit with bulb comprising one arm, the resistance of which changes with temperature. Other bridge arms fixed. Source of energy, such as batteries, is required.

CONSTRUCTION: Normally wound with a high temperature coefficient wire, such as nickel, to give large change in resistance with temperature. Inclosed in special aluminum or steel mounting for protection. Arranged to mount into medium being tested. Usually adjusted to 100 ohms at 25 deg. C.

THERMOCOUPLE

OPERATION: Two dissimilar metals joined at one end and connected to a d.c. mechanism at the other end can measure temperature. Voltage produced across the instrument end is function of the materials used, and the temperature difference between hot and cold end. Needs external source of energy.

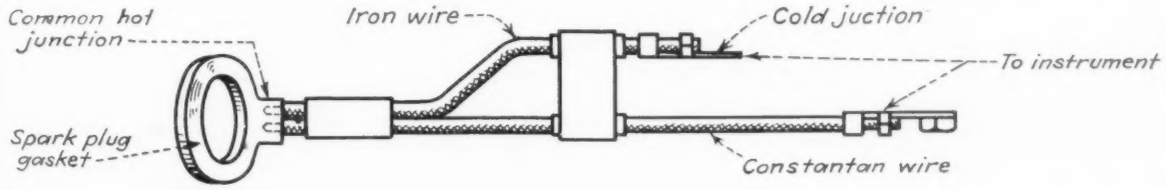
CONSTRUCTION: Two dissimilar metal wires, welded together at one end and provided with means to connect to instrument circuit at other end. Combinations with generated voltage from 0 to 100 deg. F. include:

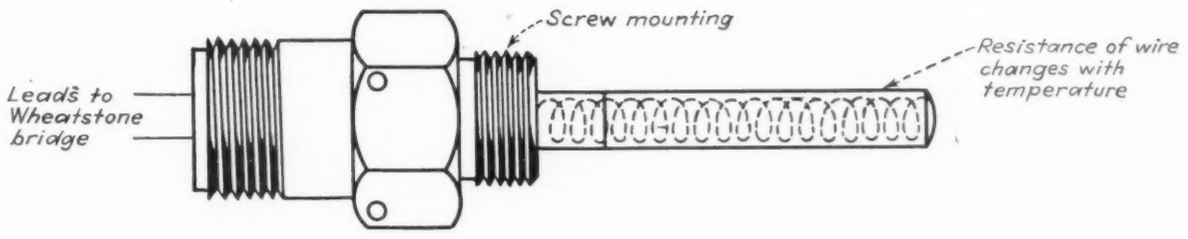
Combination	Micro-volts per deg. F.
Copper—constantan	23.0
Iron—constantan	28.8
Chromel—Alumel	22.0
Plat—Plat 10 percent iridium	3.1

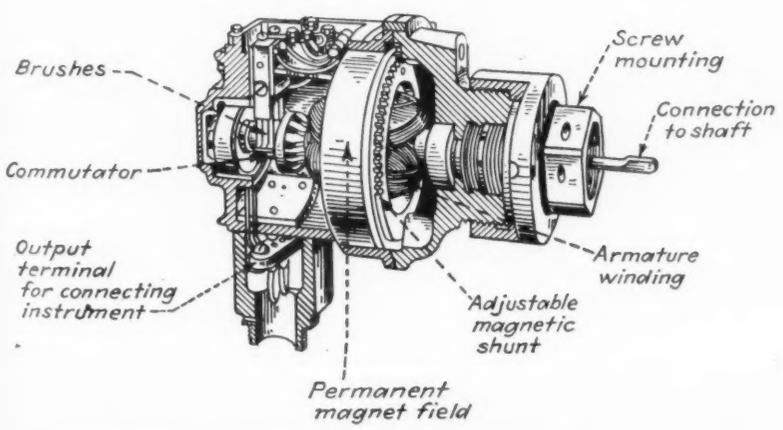
MAGNETO

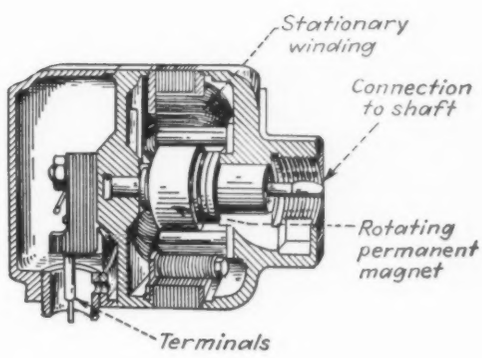
OPERATION: A generator, either a.c. or d.c., so constructed that the voltage generated is a function of speed. Either type uses a permanent magnet to provide the field flux. In the a.c. type, the magnet rotates and the winding is stationary; in the d.c., the armature winding rotates and commutator and brushes are used. Generated voltage is of the order of 6 to 10 volts per 1,000 r.p.m. Resistance of the magneto windings varies from 20 to 200 ohms depending on type.

CONSTRUCTION: Both a.c. and d.c. generators arranged for direct coupling to shaft the speed of which is being measured. Housing and mounting details differ for different applications. D.c. type usually has special alloy commutator and brushes for long service. High coercive force magnets such as Alnico II or 35 percent cobalt steel used.









DESIGNING FOR ECONOMY

Of Material Tooling Labor

KENNETH W. SCHMIDT
Production Design Engineer, North American Aviation, Inc.

Table I — Cost of Raw Stock

Material		Cost per pound, dollars	Cost per cu.in., dollars
Bar and Sheet			
Carbon steel, hot-rolled		0.05	0.014
Carbon steel, cold-finished		0.07	0.020
Chrome-moly steel, hot-rolled, norm.		0.11	0.031
Chrome-moly steel, hot-rolled, heat-treated (Purchased up through 1¼ dia. bar)		0.13	0.037
Chrome-moly steel, cold-finished, norm.		0.15	0.043
Carbon steel, zinc plated, cold-finished, sheet		0.16	0.045
Chrome-moly steel, cold-finished, heat-treated (Purchased up through 1¼ dia. bar)		0.17	0.048
Brass		0.20	0.063
Aluminum alloy, 24SO, bare or clad		0.31	0.031
Aluminum alloy, 24ST, bare or clad		0.34	0.034
Bronze, phosphorus		0.38	0.120
Corrosion resistant steel	approx.	0.40	0.114
Magnesium alloy, bar		0.45	0.029
Phenolic fibre, sheet		0.70	0.035
Extrusions			
Aluminum alloy extrusion—SO (More than 0.25 sq.in. cross-sectional area)		0.40	0.040
Aluminum alloy extrusion—ST (More than 0.25 sq.in. cross-sectional area)		0.44	0.044
Aluminum alloy extrusion—SO (Less than 0.25 sq.in. cross-sectional area)		0.55	0.055
Aluminum alloy extrusion—ST (Less than 0.25 sq.in. cross-sectional area)		0.60	0.060
Sand Castings			
Carbon steel		0.25	0.071
Chrome-moly steel, heat-treated		0.60	0.170
Corrosion resistant steel		0.90	0.256
Aluminum alloy, heat-treated		1.15	0.115
Magnesium alloy, heat-treated		2.25	0.146
Permanent Mold Castings			
Aluminum alloy, heat-treated	approx.	1.10	0.110
Magnesium alloy, heat-treated	approx.	2.15	0.140
Die Castings			
Chrome-moly steel, heat-treated	approx.	0.65	0.185
Aluminum alloy, heat-treated	approx.	1.00	0.100
Magnesium alloy, heat-treated	approx.	2.00	0.130

LOWER COSTS through designing for economy in material, tooling and labor are under the control of the design engineer. It was impossible to keep costs at a minimum during the war years as many design changes were necessary without interrupting the production schedule. Getting into production quickly and maintaining high production rates were paramount. Cost is of greater importance under today's more normal conditions.

A successful company's product must be produced in the most economical manner consistent with an established standard of quality. While designs must be prepared as quickly as possible, careful consideration should be given to the feasibility of the product from a production standpoint.

Material cost varies between the raw material necessary to make an article and the material in the finished part. In cost comparisons of similar parts, the actual part shown on the drawing may be cheaper if made from one material than from another, although the raw material cost may be greater. Since it is up to the designer to specify the raw material on the drawing, he controls material cost. The design engineer may call out a forging costing 75 cents a pound, or a piece of steel sheet costing 6 cents a pound.

Material cost tables, such as those illustrated by Tables I, II and III, have been found most helpful as a guide to the design engineer in selecting the proper material. Although these tables pertain to the cost of raw and semifinished materials used in airframe construction, tables of the same type can be compiled to apply to any industry. The values represent relative costs to the company rather than actual costs and are based upon average basic cost for normal production orders. For example, normal production orders of tubing are assumed to be from 500 to 999 ft. The cost increases considerably for smaller quantities, being twice as much for 25 to 100 ft. and about two and one half times as much for less than 25 ft. If large quantities, 5,000 ft. or more, of the same size tubing are ordered at one time, reductions up to 20 percent are possible.

Actual cost records show a wide variation with the prices in the tables. For bar and sheet, much of this variation is the result of the intricate method of determining prices with extras and/or deductions for quantity,

Table II — Cost Per Foot in Dollars of S.A.E. 4130 Seamless, Round Steel Tubing, Aircraft Quality

Outside Diameter	Wall Thickness, in.																								
	0.020	0.022	0.025	0.028	0.032	0.035	0.042	0.049	0.058	0.065	0.072	0.083	0.095	0.109	0.125	0.134	0.156	0.188	0.219	0.250	0.281	0.313	0.375	0.438	0.500
3/16	0.15	0.14	0.14	0.14																					
1/4	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.17															
5/16	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.17	0.18	0.20													
3/8	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.17	0.18	0.20	0.21												
7/16	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.17	0.18	0.20	0.21												
1/2	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.17	0.18	0.20	0.21	0.22	0.23	0.24									
9/16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.19	0.21	0.22	0.23	0.25	0.27	0.29	0.30									
5/8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.19	0.21	0.22	0.23	0.25	0.27	0.29	0.30									
3/4	0.16	0.16	0.16	0.16	0.16	0.16	0.18	0.20	0.22	0.24	0.25	0.27	0.29	0.32	0.34	0.35	0.39	0.43							
7/8	0.18	0.18	0.17	0.17	0.17	0.17	0.19	0.21	0.24	0.26	0.28	0.30	0.33	0.35	0.38	0.41	0.46	0.50	0.55						
1	0.19	0.19	0.19	0.19	0.18	0.18	0.20	0.23	0.26	0.29	0.32	0.35	0.38	0.40	0.43	0.45	0.52	0.57	0.63	0.68					
1 1/8	0.21	0.21	0.20	0.20	0.20	0.20	0.22	0.24	0.27	0.30	0.34	0.37	0.42	0.45	0.48	0.51	0.57	0.65	0.73	0.76					
1 1/4	0.23	0.23	0.22	0.22	0.21	0.21	0.24	0.26	0.29	0.32	0.36	0.40	0.45	0.48	0.51	0.55	0.61	0.71	0.77	0.84	0.90	0.94	1.05		
1 3/8		0.31	0.30	0.30	0.29	0.29	0.28	0.28	0.31	0.35	0.38	0.42	0.47	0.50	0.54	0.59	0.66	0.76	0.82	0.90	0.95	1.06	1.20		
1 1/2		0.34	0.33	0.32	0.31	0.30	0.29	0.30	0.34	0.37	0.41	0.45	0.49	0.53	0.58	0.62	0.71	0.82	0.90	0.97	1.08	1.20	1.33		
1 5/8		0.38	0.36	0.35	0.33	0.32	0.31	0.32	0.36	0.40	0.44	0.48	0.52	0.56	0.62	0.67	0.76	0.88	0.98	1.08	1.19	1.33	1.48	1.66	
1 3/4			0.51	0.49	0.47	0.46	0.45	0.44	0.43	0.44	0.48	0.51	0.56	0.62	0.67	0.72	0.81	0.94	1.06	1.17	1.30	1.46	1.64	1.84	
1 7/8			0.55	0.52	0.50	0.48	0.47	0.46	0.45	0.46	0.50	0.54	0.60	0.66	0.71	0.76	0.86	1.02	1.14	1.27	1.40	1.55	1.75	2.02	
2			0.58	0.55	0.53	0.50	0.49	0.48	0.47	0.48	0.53	0.57	0.62	0.69	0.74	0.82	0.92	1.09	1.22	1.38	1.52	1.65	1.92	2.19	2.40
2 1/8			0.63	0.60	0.58	0.55	0.53	0.52	0.51	0.52	0.56	0.60	0.66	0.73	0.78	0.86	0.99	1.17	1.32	1.48	1.63	1.80	2.06	2.34	2.60
2 1/4			0.66	0.63	0.60	0.57	0.55	0.54	0.53	0.54	0.58	0.63	0.69	0.76	0.83	0.91	1.05	1.24	1.39	1.58	1.74	1.89	2.20	2.54	2.80
2 3/8			0.70	0.66	0.63	0.60	0.58	0.57	0.56	0.57	0.62	0.66	0.73	0.80	0.87	0.97	1.11	1.32	1.48	1.68	1.86	2.01	2.40	2.71	3.00
2 1/2			0.73	0.68	0.65	0.63	0.62	0.60	0.59	0.60	0.64	0.68	0.75	0.83	0.92	1.02	1.17	1.39	1.57	1.80	1.98	2.15	2.55	2.89	3.20
2 5/8					0.84	0.80	0.77	0.75	0.73	0.71	0.70	0.71	0.78	0.87	0.95	1.06	1.22	1.45	1.67	1.89	2.10	2.30	2.68	3.06	3.40
2 3/4					0.88	0.84	0.80	0.77	0.75	0.73	0.71	0.73	0.82	0.91	1.00	1.11	1.28	1.53	1.76	1.96	2.21	2.43	2.83	3.24	3.60
2 7/8					0.91	0.87	0.84	0.82	0.79	0.76	0.75	0.76	0.84	0.95	1.04	1.15	1.33	1.59	1.83	2.07	2.25	2.48	2.90	3.42	3.80
3						1.00	0.96	0.93	0.90	0.87	0.86	0.85	0.86	0.99	1.12	1.19	1.37	1.63	1.90	2.13	2.37	2.61	3.05	3.59	4.00
3 1/8						1.06	1.02	0.99	0.96	0.94	0.92	0.91	0.92	1.06	1.15	1.28	1.48	1.76	2.03	2.30	2.56	2.82	3.30	3.77	4.20
3 1/4						1.12	1.08	1.04	1.00	0.97	0.96	0.95	0.96	1.10	1.20	1.34	1.55	1.84	2.12	2.40	2.67	2.94	3.45	3.95	4.40
3 3/8						1.17	1.12	1.08	1.04	1.02	1.00	0.99	1.00	1.14	1.25	1.39	1.61	1.92	2.21	2.50	2.78	3.06	3.60	4.12	4.60
3 1/2						1.23	1.17	1.13	1.10	1.05	1.04	1.03	1.04	1.18	1.30	1.44	1.67	1.99	2.30	2.60	2.90	3.19	3.75	4.30	4.80
3 5/8							1.46	1.40	1.35	1.29	1.25	1.23	1.22	1.23	1.35	1.50	1.74	2.06	2.38	2.70	3.01	3.31	3.90	4.47	5.00
3 3/4							1.52	1.45	1.40	1.34	1.30	1.27	1.26	1.27	1.38	1.55	1.80	2.14	2.47	2.80	3.13	3.44	4.05	4.65	5.20
4								1.80	1.71	1.64	1.57	1.52	1.49	1.48	1.49	1.66	1.93	2.29	2.65	3.00	3.35	3.68	4.35	5.00	5.60
4 1/4										2.02	1.94	1.84	1.80	1.77	1.75	1.77	2.04	2.44	2.82	3.20	3.57	3.95	4.66	5.35	6.00
4 1/2										2.15	2.06	1.98	1.92	1.88	1.82	1.88	2.17	2.60	3.00	3.40	3.80	4.40	4.95	5.70	6.41
4 3/4										2.28	2.18	2.09	2.04	1.98	1.97	1.98	2.29	2.74	3.18	3.60	4.02	4.45	5.25	6.05	6.80
5										2.40	2.30	2.20	2.15	2.09	2.08	2.09	2.42	2.90	3.35	3.80	4.25	4.70	5.60	6.40	7.21

Table III — Cost Per Foot in Dollars of 24ST Aluminum Alloy Round Tubing For 24SO Use the Same Costs; for 52SO Use 80 Percent of the Costs

Outside Diameter	Wall Thickness, in.																						
	0.020	0.022	0.025	0.028	0.032	0.035	0.042	0.049	0.058	0.065	0.072	0.083	0.095	0.109	0.125	0.134	0.156	0.188	0.219	0.250	0.375	0.500
3/16	0.07	0.06	0.05	0.04	0.04	0.04																
1/4	0.07	0.06	0.05	0.04	0.04	0.04	0.05	0.06	0.07	0.08												
5/16	0.07	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.08	0.08	0.09										
3/8	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09									
7/16	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09									
1/2	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10	0.11	0.12	0.12	0.13	0.14	0.14						
9/16	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.17	0.18						
5/8	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.17	0.18						
3/4	0.09	0.09	0.09	0.09	0.09	0.10	0.11	0.12	0.13	0.15	0.16	0.18	0.19	0.21	0.22	0.23	0.25	0.28				
7/8	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.14	0.16	0.17	0.18	0.20	0.22	0.23	0.25	0.27	0.30	0.33	0.36			
1	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.15	0.17	0.19	0.21	0.23	0.25	0.26	0.28	0.29	0.34	0.37	0.41	0.44		
1 1/8	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.16	0.18	0.19	0.22	0.24	0.27	0.29	0.31	0.33	0.37	0.42	0.47	0.49		
1 1/4	0.15	0.15	0.15	0.14	0.14	0.14	0.15	0.17	0.19	0.21	0.23	0.26	0.29	0.31	0.33	0.36	0.40	0.46	0.50	0.55	0.68	
1 3/8		0.23	0.22	0.21	0.20	0.21	0.21	0.22	0.22	0.23	0.25	0.27	0.31	0.33	0.35	0.38	0.43	0.49	0.53	0.59	0.78	
1 1/2		0.27	0.26	0.25	0.24	0.23	0.22	0.23	0.23	0.24	0.27	0.29	0.32	0.35	0.38	0.40	0.46	0.53	0.59	0.63	0.87	
1 5/8		0.31	0.30	0.29	0.28	0.27	0.26	0.25	0.25	0.26	0.29	0.31	0.34	0.36	0.40	0.44	0.49	0.57	0.64	0.70	0.96	
1 3/4			0.32	0.31	0.30	0.29	0.27	0.26	0.27	0.28	0.30	0.33	0.36	0.40	0.44	0.47	0.53	0.61	0.69	0.76	1.07	
1 7/8			0.35	0.34	0.33	0.31	0.29	0.28	0.29	0.30	0.33	0.35	0.39	0.43	0.46	0.49	0.56	0.66	0.74	0.83	1.14	
2			0.38	0.37	0.35	0.34	0.32	0.30	0.31	0.32	0.34	0.37	0.40	0.45	0.48	0.53	0.60	0.71	0.79	0.90	1.25	1.56
2 1/8			0.41	0.39	0.38	0.36	0.35	0.34	0.33	0.34	0.36	0.39	0.43	0.47	0.51	0.56	0.64	0.76	0.86	0.96	1.34	1.69
2 1/4			0.43	0.41	0.39	0.37	0.36	0.35	0.35	0.35	0.38	0.41	0.45	0.49	0.54	0.59	0.68	0.81	0.90	1.03	1.43	1.82
2 3/8			0.46	0.43	0.41	0.39	0.38	0.37	0.37	0.37	0.40	0.43	0.47	0.52	0.57	0.63	0.72	0.86	0.96	1.09	1.56	1.95
2 1/2			0.48	0.44	0.42	0.41	0.40	0.39	0.38	0.39	0.42	0.44	0.49	0.54	0.60	0.66	0.76	0.90	1.02	1.17	1.66	2.08
2 5/8					0.55	0.52	0.50	0.49	0.47	0.46	0.46	0.46	0.51	0.57	0.62	0.69	0.79	0.94	1.08	1.23	1.74	2.21
2 3/4					0.57	0.55	0.52	0.50	0.49	0.47	0.46	0.47	0.53	0.59	0.65	0.72	0.83	0.99	1.14	1.27	1.84	2.34
2 7/8					0.59	0.57	0.55	0.53	0.51	0.50	0.49	0.50	0.55	0.62	0.68	0.75	0.86	1.03	1.19	1.35	1.89	2.47
3						0.65	0.62	0.60	0.59	0.57	0.56	0.55	0.56	0.64	0.73	0.77	0.89	1.06	1.23	1.39	1.98	2.60
3 1/8						0.69	0.66	0.64	0.62	0.61	0.60	0.59	0.60	0.69	0.75	0.83	0.96	1.14	1.32	1.49	2.14	2.73
3 1/4						0.73	0.70	0.68	0.65	0.63	0.62	0.62	0.62	0.72	0.78	0.87	1.01	1.19	1.38	1.56	2.24	2.86
3 3/8						0.76	0.73	0.70	0.68	0.66	0.65	0.64	0.65	0.74	0.81	0.90	1.05	1.25	1.44	1.63	2.34	2.99
3 1/2						0.80	0.76	0.73	0.72	0.68	0.68	0.67	0.68	0.77	0.85	0.94	1.09	1.29	1.49	1.69	2.42	3.12
3 5/8							0.95	0.91	0.88	0.84	0.81	0.80	0.79	0.80	0.88	0.98	1.12	1.34	1.55	1.76	2.54	3.25
3 3/4							0.99	0.94	0.91	0.87	0.85	0.83	0.82	0.83	0.90	1.01	1.17	1.39	1.61	1.82	2.64	3.38
4								1.17	1.11	1.07	1.02	0.99	0.97	0.96	0.97	1.08	1.25	1.49	1.73	1.95	2.83	3.64

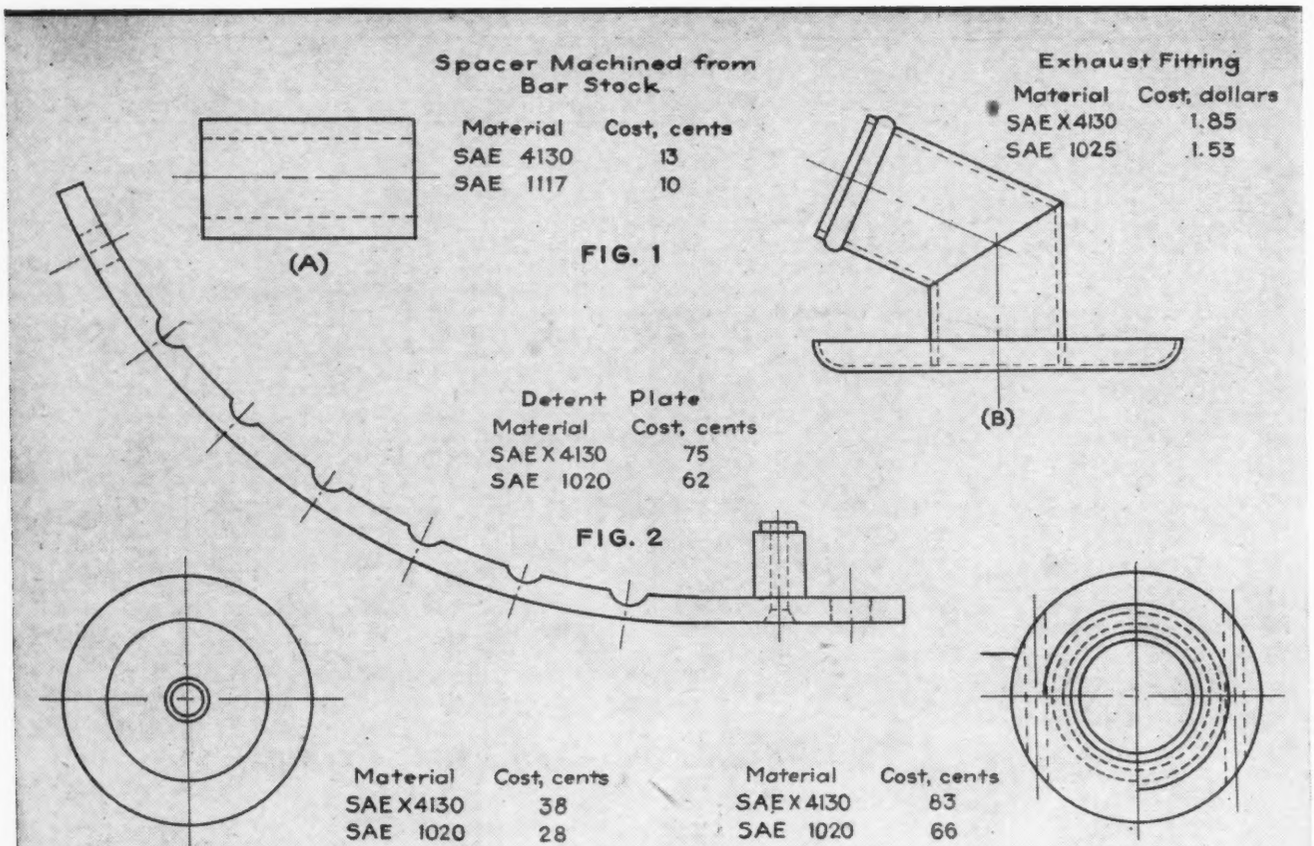


Fig. 1—(A) Simple spacer machined from bar stock; (B) Exhaust fitting fabricated from sheet and tube stock. Fig. 2—Detent plate that is machined from sheet stock. Fig. 3—Retainers machined from bar stock.

gage, width, length, tolerance, finish, analysis and treatment. Quantity is the major reason for cost differences, especially for tubing and extrusions. Where the quantity required is large, the relative cost per unit is low. The tables are compiled to show the true cost relation when all factors remain equal.

Adjustments must often be made in cost data for castings and forgings because design, type of equipment and schedules all modify cost. Castings and forgings are often bought by the piece instead of by the pound. Forgings as a rule are priced per unit.

Die castings are also bought by the piece, but the vendor usually does the machining as well. The designer should not overlook this item when comparing relative costs. Many comparative estimates on die and permanent mold castings versus sand casting or bar stock show that die and permanent mold castings are more practical only if production is to exceed a thousand pieces. Few dies and molds for forgings, die castings and permanent mold castings cost less than 500 dollars.

Popular sizes for bar and sheet are listed in the tables. Sheet stock 0.025 in. and thinner, and bar stock 5/16 in. and smaller are more expensive. The price of SAE 2300 series steels is comparable to the price of chromium-molybdenum steels. The aluminum alloys 2S, 3S and 52S are slightly less in cost than the 24S series listed in Tables I and III, while 24SRT and the 75S series are more expensive.

Items to the left of the heavy lines in Table II and III are in less demand and consequently are more expensive and are not as readily available. Table II can be used for SAE 1025 aircraft quality steel tubing for sizes 3/4 in. and less. For sizes larger than 3/4 in. use 75 percent of the tabulated price.

Remarks like the foregoing can be associated with relatively few tables to give the designer a good coverage of cost data. If preferred, more tables can be compiled, one for each material, but too many tables serve no useful purpose. The idea is to supply concise information to guide the designer in selecting materials where the differences in cost are appreciable—not to burden him with minor differences.

The cost of the finished parts will not necessarily reveal the same comparison as the cost of raw materials, because of different methods of fabrication. The estimated costs might also differ from the true costs. Unit costs instead of dollars cost are preferred by some companies.

Weight to volume ratios of the various materials are often needed when comparing costs. The following

relations are satisfactory for all cost calculations:

Material	Weight, lb. per cu. in.
Phenolic plastic	0.050
Magnesium alloy	0.065
Aluminum alloy	0.100
Steel	0.284
Brass and bronze	0.315

Standard parts or parts already in production can often be used or adapted to new designs. They should be used wherever practicable, since they are more economical to manufacture and also save time and effort of the designer.

Simple parts need to be analyzed for cost as well as heavy, complex parts. Figs. 1, 2 and 3 illustrate parts where changes in material effected savings. Although a few cents saved on a single piece may appear trivial, substantial savings can be realized when thousands of pieces are required.

Under the modern assembly line system of manufacture, purchased parts have become increasingly important and it is necessary to purchase these parts on the basis of quality, delivery and price. Many parts are specified on the drawing from a favorite manufacturer's catalog without investigating the possibility of an available substitute that is less expensive. An example is cited of a heat-treated, chromium-molybdenum steel nut purchased at a cost of $3.37 as part of the engine mount bushing assembly. The high cost brought about an investigation that disclosed that a high strength nut was not necessary. A 14ST aluminum alloy, hollow, hexagonal extrusion was used and the nuts machined from it at a cost of 30 cents each. Since each airplane required 10 of these nuts, this one substitution showed a saving of $30,700 on a thousand planes, plus a substantial saving in weight.

Tooling Cost

Tooling costs can be kept at a minimum by properly designing parts. This is apart from the fact that a small amount invested in tooling will result in high labor costs or, conversely, low labor costs can be achieved by spending an adequate sum on tooling. The amount of tooling can be adjusted to the expected volume of production. This fact is sometimes overlooked, but it is of great importance in planning tooling and the method of making the part.

A fitting is shown in Fig. 4. This part can be machined either from an aluminum alloy sand casting or from bar stock. An analysis of the comparative costs of the parts manufactured by the two methods is as follows:

	Sand Casting	Bar Stock
Material	$0.20	$0.13
Machining	0.69	0.74
Cost each	0.89	0.87
Pattern and tooling (pro-rated over 1,000 parts)	0.10	0.00
Total cost each	$0.99	$0.87

In addition to the 12 cents saving in using bar stock over the sand casting, there is another factor favoring the bar stock design, namely, that a fine surface finish is more easily attained than in a casting.

A wing attaching link is shown in Fig. 5. Originally this part was designed to be rough machined from an SAE 4140 steel bar measuring 1-3/4 x 2-5/8 x 4-1/8 in. and subsequently heat-treated to a strength of from 160,000 to 180,000 lb. per sq. in. The design was replaced before going into production by a copper furnace brazed assembly. This example illustrates the saving that can be made despite higher initial tooling costs and is shown by a cost comparison of the two designs:

	Copper Furnace Brazed	Bar Stock
Material	$0.32	$0.94
Labor and burden	2.53	2.83
Cost each	2.85	3.77
Tooling (pro-rated over 1000 parts)	0.64	0.35
Total cost each	$3.49	$4.12

The lower cost of material and labor more than offsets the increased tooling cost for the copper furnace brazed design, making a saving of $630 per 1,000 planes. The point at

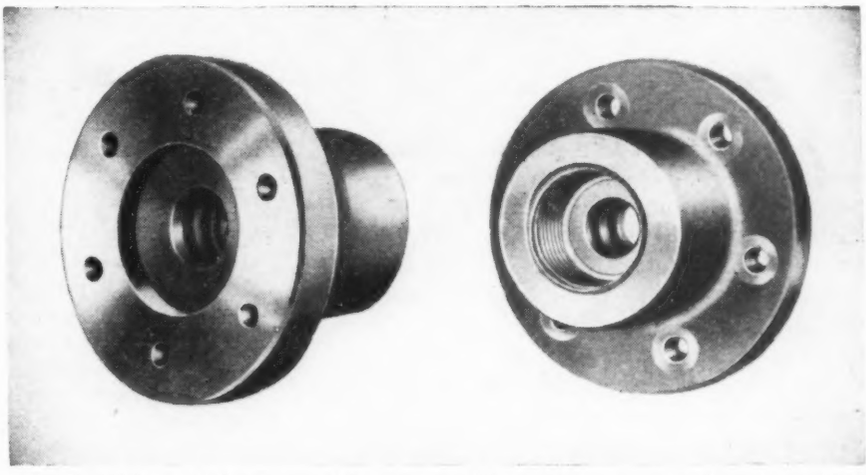


Fig. 4—Fitting of better quality was machined at lower cost from bar stock than from a casting.

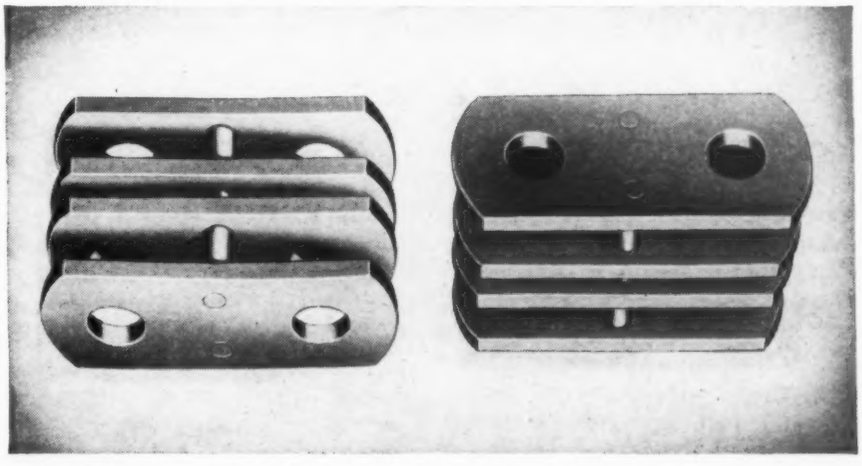


Fig. 5—This part was made by copper brazing at a saving of 63 cents over a comparable milled part.

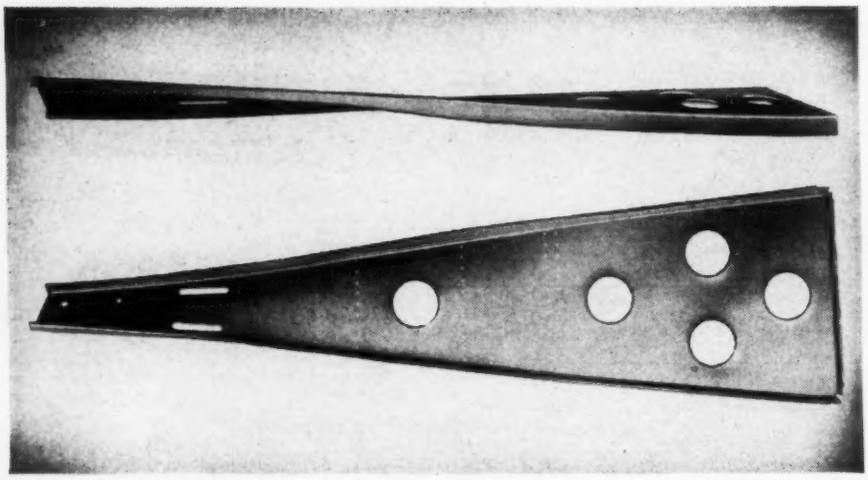


Fig. 6—Distortion of this bulkhead, which is over 6 ft. long, was eliminated by the use of 24ST clad aluminum alloy sheet.

which the costs break even in the foregoing comparison is 320 parts. If the total number of parts required is less than 320, the bar stock design will be the cheaper; while the copper furnace brazed design will be the cheaper if more than 320 parts are required.

Labor Cost

Labor cost can also be controlled by the designer as well as material and tooling costs. Any reduction in the number of operations necessary to make a part will result in a corresponding saving in labor.

For instance the advisability of using 24ST clad aluminum alloy instead of 24SO for sheet metal parts has received a great deal of study throughout the aircraft industry. Results from various reports are conclusive in favoring the preheat-treated material 24ST, provided the part can be successfully formed in this condition. When there is doubt as to whether or not the tempered material can be used, as for example on convex flanges or heavy gage hydropress parts, it is advisable to contact production design personnel.

Some advantages of using 24ST material are: (1) The cost of heat-treating with expensive equipment is eliminated; (2) the cost of hardness testing and stamping each part plus any hand straightening is avoided; (3) the time involved in items (1) and (2) in addition to the extra refrigerating, handling and trucking, all tend to delay production and increase costs and (4) the 24ST material in the "as received" condition possesses better and more uniform properties than does 24SO material heat-treated after fabrication in most industries. Usually the advantages outweigh the disadvantages, but in order to compare the two the following disadvantages are given: (1) The 24ST material cannot be used where an appreciable amount of shrink is involved, and (2) more care must be taken with tooling, as larger bend radii are necessary and springback is greater than for 24SO alloy.

The following example is typical of the savings that are possible by using 24ST material instead of 24SO. The bulkhead shown in Fig. 6 was formed from 24SO clad aluminum alloy sheet and then heat-treated. Although the material thickness was 0.081 in., the part warped excessively, requiring a great deal of hand straightening in order to pass inspection. A cost comparison between making the part from material in the "SO" and "ST" conditions is given as follows:

	24SO	24ST
Material cost	$4.35	$4.75
Labor and burden	2.94	2.06
Cost each	$7.27	$6.81

This saving of 46 cents per part represented an appreciable sum when totaled over the complete contract. The labor saved more than offsets the cost of material, but there are intangible factors too, which, if they could be evaluated, would reflect still greater savings.

German Open-Center Hydraulic Systems

OPEN-CENTER HYDRAULIC SYSTEMS for aircraft were used successfully on a large scale in Germany during the war, according to a 439-page report by the Office of Technical Services, Department of Commerce.

German design and construction of both hydraulic and fuel systems differ greatly from those used in the United States. Some of the unusual features may be applicable in current American development, according to Robert H. Davies and Lester J. Henderson, who prepared the report for the Technical Industrial Intelligence Committee, predecessor to OTS' Technical Industrial Intelligence Division.

Since open-center hydraulic systems need to be kept under pressure only when they are used for operation, the Germans were able to omit the unloading valve and the accumulator required in American hydraulic systems. This eliminated the weight and other problems which arose with the use of accumulators and unloading valves.

Unless the accumulator is of disproportionately large size, little or no gain in overall speed of operation is realized, according to German hydraulic engineers. The Germans found that, although the accumulator speeded up operation of the system in the early part of the cycle, in the latter part of the cycle, when the load was heavier, the pump wasted much of its output in recharging the accumulator. Sometimes the accumulator caused such rapid operation in the early part of the cycle that restrictor valves or constant flow valves had to be used to avoid undue acceleration forces, German engineers stated.

Omission of the unloading valve permitted use of components with higher leakage rates, according to the report. Consequently, simpler, lower-cost valves, of the slide type, could be used. By using slide type valves, the Germans were able to accomplish many complicated hydraulic operations and flow patterns.

Another advantage was that hydraulic balancing of the units could be accomplished easily, and fewer packings were needed. As a result the performance of the system was improved, the force required to operate the valves could be reduced, and a simpler design could be worked out.

ENGINEERING ABSTRACTS

FOREIGN AND DOMESTIC ARTICLES

Possible Uses of Microwaves for Industrial Heating

From "Microwaves and Their Possible Use in High Frequency Heating", by J. Marcum, Research Engineer and T. P. Kinn, Engineering Division Manager, Industrial Electronics Div., Westinghouse Electric Corp., presented at Second National Electronics Conference.

MANY WORTHWHILE APPLICATIONS of dielectric heating are not practicable today because radio power at conventional frequencies limit the speed of heating. At some future time heating speeds may be tremendously increased by using microwave power. Although limitations of power and application techniques places actual applications well into the future, it is interesting to speculate how microwave tubes and techniques now available could eventually be used for dielectric heating at ultra high speed.

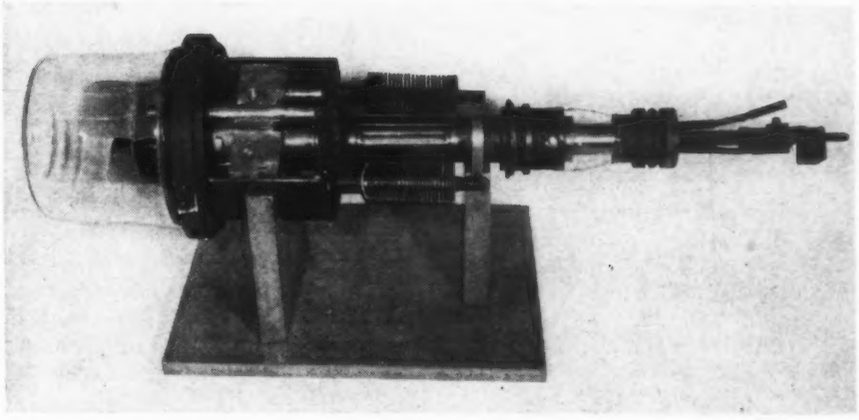


Fig. 1—Ten kw. split-anode magnetron for 60 cm. wave length. This type of generator is one of the two most promising for high frequency heating.

Today, large scale production by dielectric heating at conventional frequencies is obtained by the use of high power industrial-type tubes. At microwave frequencies the present sources of radio frequency power, shown in Table I, are definitely limited. At present, the only tube in large scale production is the "resonant cavity" type magnetron for pulsed operation. These tubes produce peak power outputs of about a megawatt or more; the average power is seldom over 1 kw., which is just on the verge of being useful for heating purposes. Pulsed operation is seldom useful for heating since the work piece is subject to large voltages during the operating time, and must be arranged to prevent breakdown.

The two tubes that seem most promising for future use in dielectric heating are the split anode magnetron and the resnatron. Although at present there is no production of the split anode magnetron shown in Fig. 1, it could be made if the need arose.

The resnatron type of tube is the only source available in the 50 kw. range. It is a beam type tetrode that can be used either as an amplifier or an oscillator. About twenty tubes have been made with these characteristics: Frequency, 400 mc.; tuning, 3 mc.; anode voltage, 30 kv.; power input, 125 kw.; power output, 50 kw.

All microwave generators are inherently voltage sensitive. The power out-

Table I—Types of High Power Microwave Tubes

Tube Type	Manufacturer	Wavelength	Output		Operation	Efficiency, Percent	Voltage, Kv.
		Range, Cm.	Cm.	Watts			
Resonant Magnetron	Western Electric Raytheon Westinghouse	1 to 30	3 10	500 2,000	Pulsed	50	10–30
Klystron	Sperry	10 to 100	10 40	100 1,000	Continuous	30	7
Split-Anode Magnetron	Westinghouse	40 to 90	60	10,000	Continuous	50	12
Resnatron	Westinghouse	10 to 100	60	50,000	Continuous	25	30

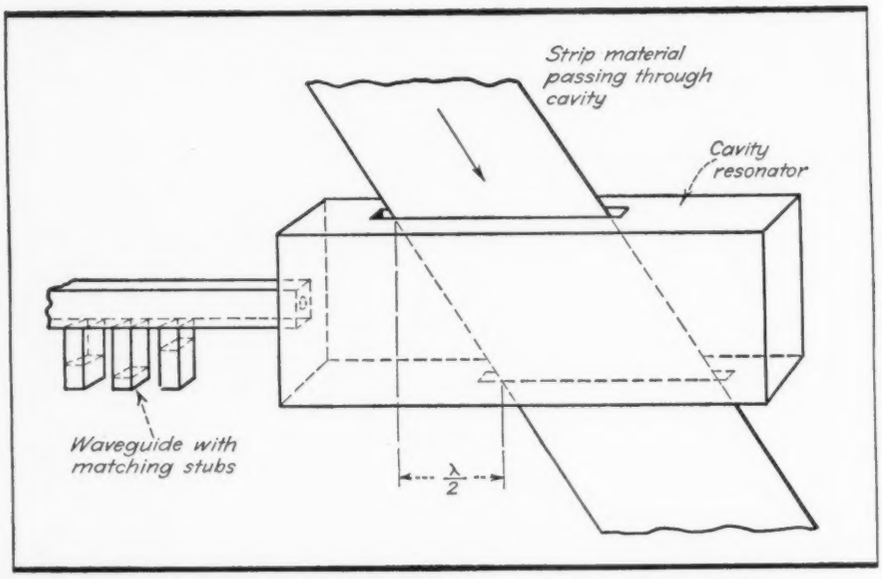


Fig. 2—Resonant cavity for continuous strip material dielectric heating.

put, and to a lesser extent the frequency, are rapidly changing functions of the applied voltage. This is because these tubes depend on the finite transit time of the electrons for their operation, which in turn depend on the voltages applied to the electrodes. If it is necessary to obtain a constant power output into a load of changing characteristics special circuits are required to control the generators.

Assuming a suitable source of R. F. power, the problems of utilizing this power for dielectric heating differ considerably from those using conventional frequencies. Ordinary open wire transmission line will not convey the power from the source to the work, because of excessive loss by radiation from such a line at microwave frequencies. Coaxial type of transmission lines are satisfactory for wavelengths as short as 10 cm. or less, under certain conditions. They do not suffer from radiation loss like the open wire line, but have other disadvantages; for example, they are inherently unbalanced with respect to ground.

At wavelengths of about 10 cm., and sometimes up to 60 cm. or greater, it is advantageous to use wave guides to transmit power instead of coaxial lines. A wave guide is simply a hollow pipe of metal, usually of circular or rectangular cross section.

When dielectric material is placed in the waveguide and causes a large standing wave to be set up, the diaphragm necessary to match the standing wave will extend across a good portion of the waveguide so that only a small opening remains. Under this condition a strong field is built up within the chamber, or "cavity resonator," containing the dielectric. The opening to such a resonator can be a round hole, and the main body of the resonator need not be the same shape as the waveguide, but may be longer or almost of any arbitrary shape. Such a cavity resonator bears resemblance to a lumped LC circuit as used at conventional frequencies in much the same way that a waveguide is related to an open wire line.

An outstanding property of microwaves is that they can be concentrated into a narrow pencil-like beam with a reasonable sized antenna structure. The beam width, to the half power points, of a parabolical radiator is:

$$B = 180\,\lambda/D \quad \text{deg.}$$

where λ is the wavelength and D the diameter of the radiator. For example, a 30 in. dish at a wavelength of 3 cm. gives a beam width of only 2.3 degrees.

There are many possible uses for the resonant cavity and antenna for dielectric heating for drying, curing or setting of resins or glues in continuous processes. For example, in the textile industry cloth is dried after dyeing both in bulk and on a continuous basis. Printed fabric requires a rapid drying cycle for the dyes and inks used. In the paper industry, drying of the material on a continuous sheet basis at high speed is required.

At conventional frequencies, even with sufficient power to do the drying of textiles and paper the power can not be forced into the work. Once frequency is set, the power into the work varies only as the square of the voltage across the electrodes.

Power varies as (frequency) (voltage)^2 (loss factor).

For thin materials, such as paper and cloth, it is impossible to apply sufficient voltage across the electrodes at conventional frequencies because the electrodes flashover before appreciable power is coupled into the dielectric work material. By using a much higher frequency, Fig. 2 shows how a cavity resonator might be used to put power into rapidly moving thin sheet material. The dielectric field is of uniform character only in one dimension, and that occurs in a plane that is a maximum at the center of the cavity or guide. By passing the material through slots at the top and bottom of the cavity it is subjected to the strong dielectric field, but because of the standing wave effect along the length of the cavity the material would be heated unevenly if passed vertically through the cavity. By making the entry and exit points ½ wavelength apart uniform heating is obtained as the material passes through the cavity.

This method of coupling microwave power could probably be applied for many commercial heating requirements such as, bonding and drying of wallboard materials, floor covering materials such as linoleum, plastic bonded cork materials, continuous curing of sheet rubber, plastics and synthetic materials, and the continuous production of plywood.

It may be possible and sometimes

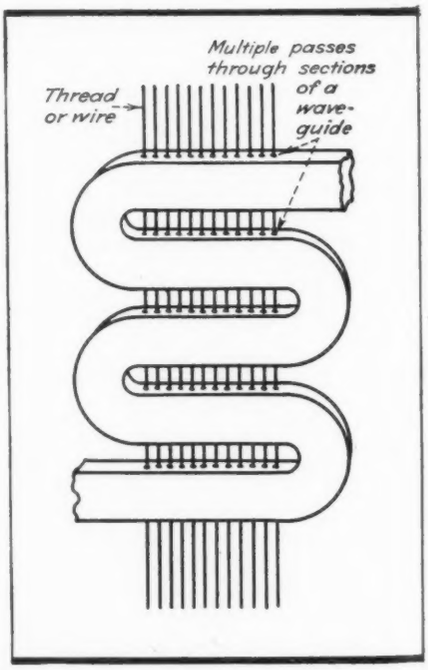


Fig. 3—For increasing energy transfer to wire or thread, a multiple pass through the waveguide can be used.

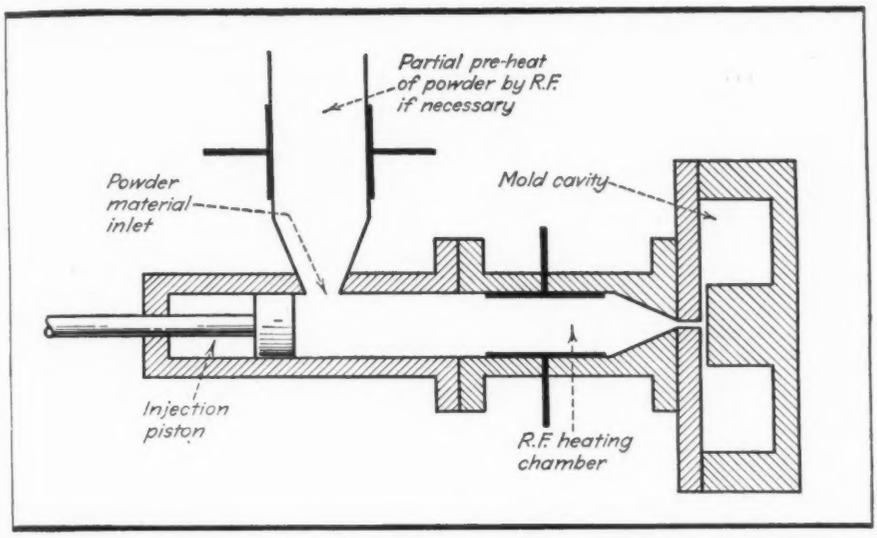


Fig. 4—Jet molding using microwave energy to preheat powder material.

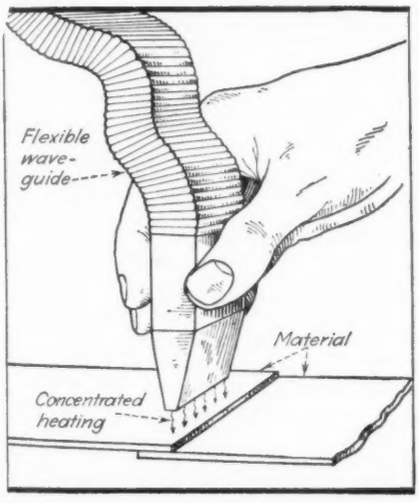


Fig. 5—A possible method for concentrating microwave energy.

desirable to heat sheet material by using a microwave or radar antenna to feed energy into a material. A so-called "bed spring" antenna with uniform distribution of field can heat large sheet material. The shape of such an antenna is flexible to a degree and therefore lends itself to the efficient heating of various widths and shapes of material.

In contrast to sheet material, such things as wire and thread can benefit from microwave heating. Textiles, such as rayon and nylon, must be cured, dried and twist set. Rubber thread material, both synthetic and pure latex, must be cured. Many insulating coatings on wire, either rubber, synthetic or enamel, must be dried or cured. All of these heating operations must be done at high speed. With conventional frequencies it has been impossible to couple energy into such material at a rate suitable for production.

Some day microwave energy fed into a long cylindrical cavity with the wire or thread to be heated racing through the center, may solve the problem. If energy transfer of such a system proves relatively inefficient, a system of multiple passes as shown in Fig. 3 may be more practical. The same principle of coupling could be applied to sheet material.

In the lumber industry many problems of gluing are still waiting for solution by dielectric heating. Spot gluing and edge gluing could be done by the concentrated fields released by openings in wave guide structures.

The plastics industry is now a big user of radio frequency energy for preheating material before molding. Conventional frequencies adequately supply the heating rates normally used for hand-fed press operation. High speed automatic operation however could now use R. F. energy to advantage if sufficiently fast heating rates could be obtained. Microwave energy possibly could be applied as shown in Fig. 4. Jet molding on an automatic basis could easily become one of the faster means of molding thermosetting material.

Microwave energy piped to numerous press positions from one central generator may be the future answer to many present molding problems. At conventional frequencies, a central generator supplying many operating positions is not too satisfactory because of the many switching, matching, and voltage problems. In contrast, the voltage and switching problems are simple when removing any degree of energy from a wave guide. Matching the guide to the generator is relatively simple because of the easy method of obtaining adjustable capacity and inductance at microwave frequencies, as compared with the limitations of lumped impedances at conventional frequencies.

Also, there is a rapidly growing demand for binding or "sewing" of sheet plastic and synthetic materials, such as the vinylidene chloride materials. Con-

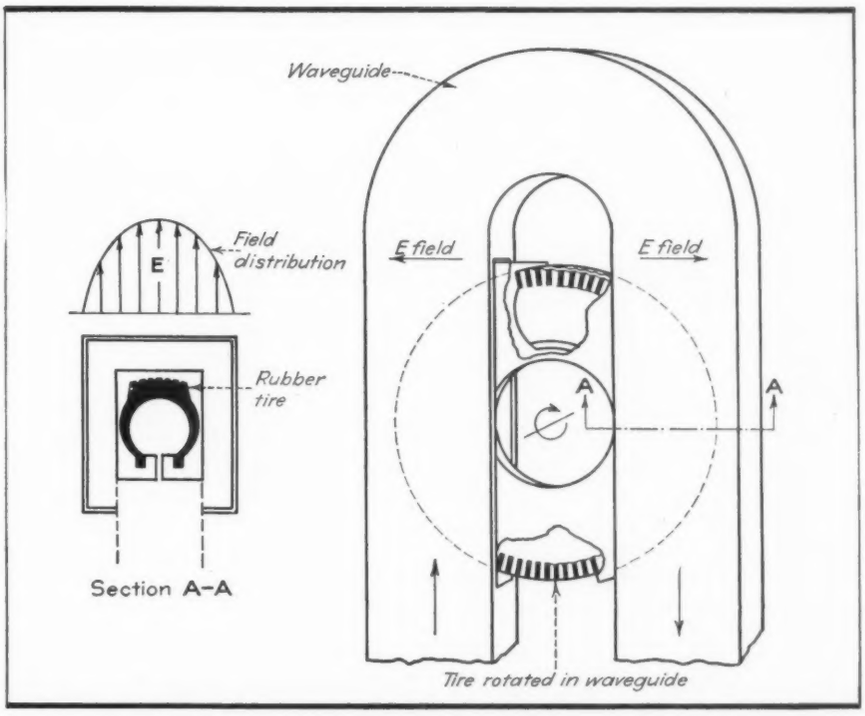


Fig. 6—Automobile tire curing by microwave energy.

ventional frequencies are relatively slow but by concentrating extremely high frequencies it may be possible to bond such sheet materials at an unbelievable rate with rather simple handling equipment. With presently available flexible wave guide material, such a bonding operation could be made semi-portable. As shown in Fig. 5, surfaces may be bonded by concentrated power. Being a very poor thermal conductor, rubber lends itself naturally to dielectric heating especially where speed and quality are of prime importance. Probably one of the most desired places for quality in a rubber product is the automobile tire. Fig. 6 shows one possible method for high-frequency heating; field distribution within a cavity is used to provide uniform curing.

The record holding food industry has many potential uses for R. F. heating, including sterilization, blanching and cooking. Much speculation on the cooking of various foods has suggested rapidly defrosting and cooking a plate of frozen meat, potatoes and vegetables. Unequal heating of the various food stuffs when subjected to an R. F. field makes this problem impractical at conventional frequencies. By using the unequal field distribution found in a cavity resonator it may just be possible that a suitable combination of frequency, cavity size, food stuffs and proper orientation of the food in the field would accomplish the result.

Although much of this discussion is speculation, the principles are fundamentally sound and may stimulate development in industrial heating by microwave energy and thus speed the development of tubes of suitable power, flexibility, life and reliability.

Fractional Horsepower Motor Standards

From a conference paper, "New NEMA Fractional Horsepower Motor Standards", by C. P. Potter, Wagner Electric Corp., presented at AIEE meeting, October 9, 1946, Indianapolis, Ind.

THE NEW NEMA SERVICE factors for fractional horsepower motors (PRODUCT ENGINEERING Nov. 1946, page 103) were obtained by determining the overloads that produce a 50 deg. C. rise on motors having an actual temperture rise at full load of 40 deg. C. These service factors are intended to be used only where the voltage and frequency are held within close limits and where the temperature surrounding the motor does not exceed 40 deg. C.

An open type, fractional horsepower motor with good operating characteristics may have a temperature rise somewhat less than 40 deg. C. The service factors were determined by assuming that the temperature rise at full load is 40 deg. C. Therefore, the use of the service factor may not absorb all of the thermal capacity of the motor, or in other words, it may be possible to use still higher overloads on certain applications without damage to the motor. The question may be asked why have conservative service factors been chosen?

There are several reasons:

1. A factor of safety is allowed to take care of low voltage, abnormal operating conditions, and high ambient temperatures. For example, electrically driven devices may be installed in rural communities where the voltage conditions are bad, and where the cost of servicing is high. Therefore, it seems to be economically sound to use service factors that give the motor manufacturer, the machinery manufacturer, and the users a chance to operate successfully under adverse conditions. Fig. 1 shows the effect of voltage variation on the temperature rise of a typical fractional horsepower motor. This indicates that a motor that will operate satisfactorily at a reasonable overload with normal voltage may have a dangerous temperature rise under abnormal voltage conditions.

2. There is a definite relationship between breakdown torque and locked current. (PRODUCT ENGINEERING, Nov. 1946, page 103.) There is a growing tendency on the part of power companies to limit the applications of motors on the basis of locked current rather than on the basis of horsepower rating. Motors with greater service factors must have more breakdown torque, resulting in higher locked currents, and it is possible that these currents may sometime cause trouble by failing to meet the requirements of the local power companies. The maximum values of locked rotor currents for single phase motors have now been standardized (PRODUCT ENGINEERING, Nov. 1946, page 103) Motors of ½ and ¾ hp. have had code letters stamped on their nameplates for several years, and in the near future motors smaller than ½ hp. will also have the code letters stamped on the nameplate.

3. The maximum efficiency of single phase motors occurs approximately at

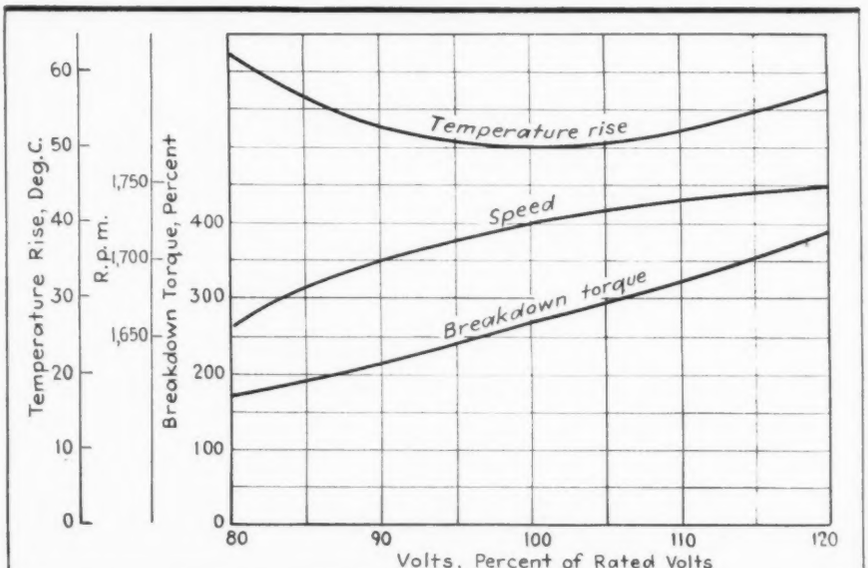


Fig. 1—Effect of abnormal line voltage on temperature rise, speed, and breakdown torque of a typical ⅓ hp. single phase, 60 cycle, 1,725 r.p.m. motor operating at 135 percent rated load at rated voltage of constant value.

the overload allowed by the service factors. If the machinery manufacturer wants the best possible overall efficiency, it is to operate the motor at these service factors. Fig. 2 shows a typical performance curve for a 1/3 hp., single phase motor that has a service factor of 1.35. The maximum efficiency occurs at 135 percent of full load, and at this load the speed of the motor is still quite high.

4. When excessive overloads are applied to any single phase motor, the speed of the motor decreases considerably, and this affects the operation of the driven machines. For example, if the speed of a motor driving a refrigeration compressor or pump drops too much, the output may be reduced to a point that makes it unsatisfactory to the user.

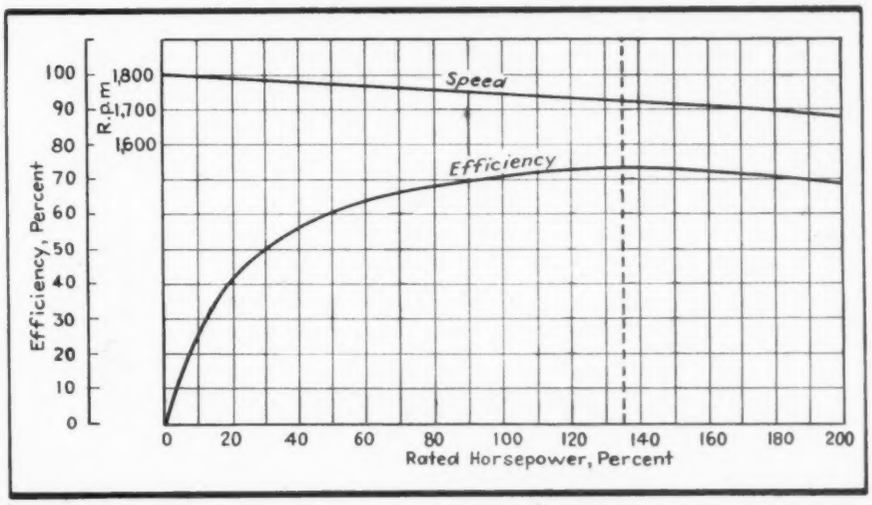


Fig. 2—Effect of horsepower on speed and efficiency of a typical 1/3 hp., single phase, 60 cycle, 1,725 r.p.m. motor. Dotted line shows best efficiency.

A manufacturer of refrigeration equipment or pumps may agree with all of these statements and at the same time may feel that the new NEMA Standards will cause him a great deal of expense and inconvenience and may make it necessary to use larger and more expensive motors for driving his equipment. The new NEMA Standards do not require any changes in the performance or capacity of motors that have been established on their applications and that are giving good service. The standards provide a consistent method of designating the rating of such motors without making any changes in the motors except perhaps the horsepower stamping on the nameplate.

It is unlikely that any motor user will need to make any changes in the applications of motors that have been applied on a sound basis with satisfactory life. Where the user is buying motors that have greater breakdown torques than those covered by NEMA Standards, it will be necessary, after a suitable period of time, to stamp the nameplates of these motors properly. If all new applications are made on the basis of the new NEMA Standards results will include.

1. Users will get motors that have a long life and will not cause losses because of fire or stoppage of production.

2. Application engineers and the appliance manufacturers will be able to select the proper motor without having to test each application.

3. Power companies will be able to connect these motors to their circuits, with the assurance that their equipment is adequate and that the operation of the motors will not cause annoyance to their customers.

Tool, Die and Special Steels

Foreign Abstract condensed from "Developments in Tool, Die and Special Steels," by G. M. Butler in *Combined Intelligence Objectives Sub-Committee, Item No. 21*

SCARCITY OF ALLOYING ELEMENTS during the war led German metallurgists to devote their efforts to the conservation of alloys. Developments of possible interest include the following:

Cold worked austenitic steels for hot extrusion dies: Steel used was of the class often used for aero exhaust valves, with 0.5-0.45 percent carbon; 13-15 percent nickel; 13-15 percent chromium, and 2 percent tungsten. After forging or rolling to billets, slugs were cut and finished into disks by heating to about 1800 deg. F. and forging so as to complete the operation when the steel had cooled off to 1300 deg. F. The final temperature depended on the desired hardness, which ranged from 300 to 400 Brinell. This method of cold-finishing was called hammer-hardening. Disks so forged were machined into rings and used for dies to extrude steel tubes. Superior performance was claimed.

High speed steel: A high-speed steel of about 0.9 to 1.0 percent carbon, 2½ percent each of molybdenum, tungsten and vanadium, and 4 percent chromium was promoted as a low tungsten substitute for the conventional 14 to 18 percent tungsten types.

Opinions varied; makers claimed it excelled the conventional types, but several users felt it was definitely inferior. The 2½-2½-2½ type has a narrow hardening range, but is less susceptible to decarburization than the higher molybdenum types.

Sintered hard carbide materials: Of interest was the use of "Tizit" (50-60 percent tungsten carbide, 10 percent chromium, 30-40 percent cobalt) as a tough lining for ball mills. Hot swaging dies were made of tungsten carbide with 13-15 percent cobalt and 2-3 percent titanium carbide.

Cutting tools of powdered aluminum, bonded with 3-5 percent chrome oxide, pressed, then sintered at a very high temperature (3600 deg. F.) were made. Performance on light metals was reported to be good, but brittleness and low heat conductivity prevented wide use.

Hard carbide tips made of nitrided carbides were advocated by one metallurgist who claimed that up to 20 percent cobalt could be used and still have the hardness of a conventional tungsten carbide with much less Cobalt. Superior cutting ability and toughness were also claimed.

Many dies and punches were made of chrome plated carbon tool steel with no intermediate plating of another metal.

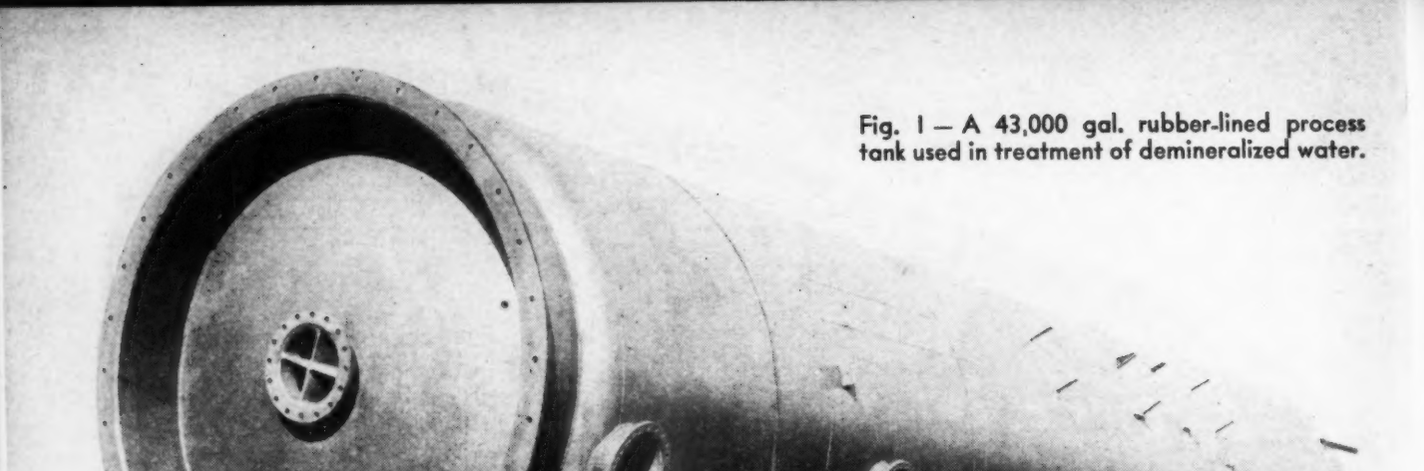


Fig. 1 — A 43,000 gal. rubber-lined process tank used in treatment of demineralized water.

Rubber Linings Protect Steel Against Corrosion and Abrasion

O. S. TRUE
United States Rubber Company

Properties of rubber in protecting cast iron and steel surfaces from the corrosive attack of gaseous and liquid chemicals. Discussion includes preparation of metal surfaces and design considerations that facilitate applying rubber linings and coatings to tanks, pipe, fittings, fans and pump impellers.

RESISTANCE to chemical corrosion, resistance to abrasion, dielectric strength and its noncontaminative properties make rubber an important material for lining tanks, pipes and other apparatus for chemical processes, the chemical industry and other engineering applications. Rubber, aided by compounding, has excellent corrosion resistance to the majority of the industrial chemicals. Exceptions are the strong oxidizing agents, such as nitric and chromic acids, certain aromatic hydrocarbons, such as benzol and toluol and the alephatic hydrocarbons, such as petroleum and its derivatives.

Since rubber has limited structural strength, it is bonded to steel in the fabrication of tanks, pipes and machinery wherein pressures and loads must be carried. The design of such equipment is made in two steps: First, the steel support is designed for strength and rigidity, which can be done according to regular design procedure. Second, the rubber coating is specified to cover those areas of the steel that need to be protected. Usually the rubber is applied to the interior surfaces of vessels and pipes so that the terminology "rubber lining" has become common usage, but rubber can be bonded with equal facility to coat exterior surfaces, of which pump impellers and fan blades are examples.

Temperature is a limitation in the use of rubber lined vessels. Under

most circumstances rubber will withstand temperatures up to 180 deg. F. Special rubber compounds will handle certain materials up to 205 or 210 deg. F., and some of the synthetics will withstand even higher temperatures, but 180 deg. F. may be regarded as a safe upper limit for general use in design calculations and process development. The practice of protecting the rubber with inner linings of brick has enabled some rubber lined equipment to be used at temperatures higher than those that could be satisfactorily handled by rubber without such special protection.

Heat or a combination of heat and pressure are necessary to vulcanize rubber to steel. The rubber lining process is sufficiently flexible to permit applications to all kinds of equipment under a wide variety of circumstances. Equipment that can be handled by rail transportation generally is shipped to a manufacturer where the rubber can be applied under factory conditions. Size is therefore a controlling factor. Since 11 feet is the usual extreme dimension in either width or height for rail shipment, most industrial equipment, including tanks, can be shipped to the factory for rubber processing.

Tanks and equipment too large for shipment can be successfully lined in the field. Application of the rubber lining then becomes a step in the construction installation. Of considerable importance to the user of rubber lined equipment is the fact that repairs to the lining can be made readily. Minor repairs are usually made by the user. Extensive projects, like initial field installations, are best handled by crews skilled in the bonding and vulcanizing process.

Design Details of Construction

Metal plates and surfaces to be rubber lined should be free from laminations or other physical imperfections, as well as from recesses, protrusions and other irregularities. Channels, I-beams, stiffeners and other structural members normally should be on the side of plate opposite to that upon which the rubber is to be vulcanized.

Steel plates before fabrication into tanks should be flat, with no appreciable buckle or warpage. Any sharp edges must be removed, especially on the inside of tanks. Machining or chipping at least 1/8 in. from sheared edges of plates is recommended. For welded construction in tanks, stacks or ducts, Table I contains plate weight requirements.

Rectangular tanks of the open top type and large plate surfaces need reinforcement to prevent bulging. Companion angles of sectional tanks that are bolted together must be square, plumb and smooth, and the sections must fit together so that the rubber lined areas will not be twisted or distorted when bolts are drawn tight. A good practice is to fit the sections before rubber lining. If the sections are permanently match marked on spots that are not to be rubber covered, they can be lined up properly afterward.

Welded construction is preferred. Plates for tanks, ducts and other parts should be designed for joining to one another and to other structural members by welding, preferably by fillet and butt welds. Fig. 2 shows alternate V- and U-type constructions of butt welds. A parallel misalignment of plates and butt weld seams up to 25 percent of the plate thickness is a satisfactory tolerance, with a maximum of 1/8 inch.

Proportions for fillet welds are shown in Fig. 3(A). Welds that are to be covered with rubber must

Table I—Weight Requirements

Nominal Plate Thickness, in.	Weight, lb. per sq. ft.
7/16	4.375
9/64	5.625
3/16	7.50
1/4	10.2
5/16	12.5
3/8	15.0
1/2	20.0

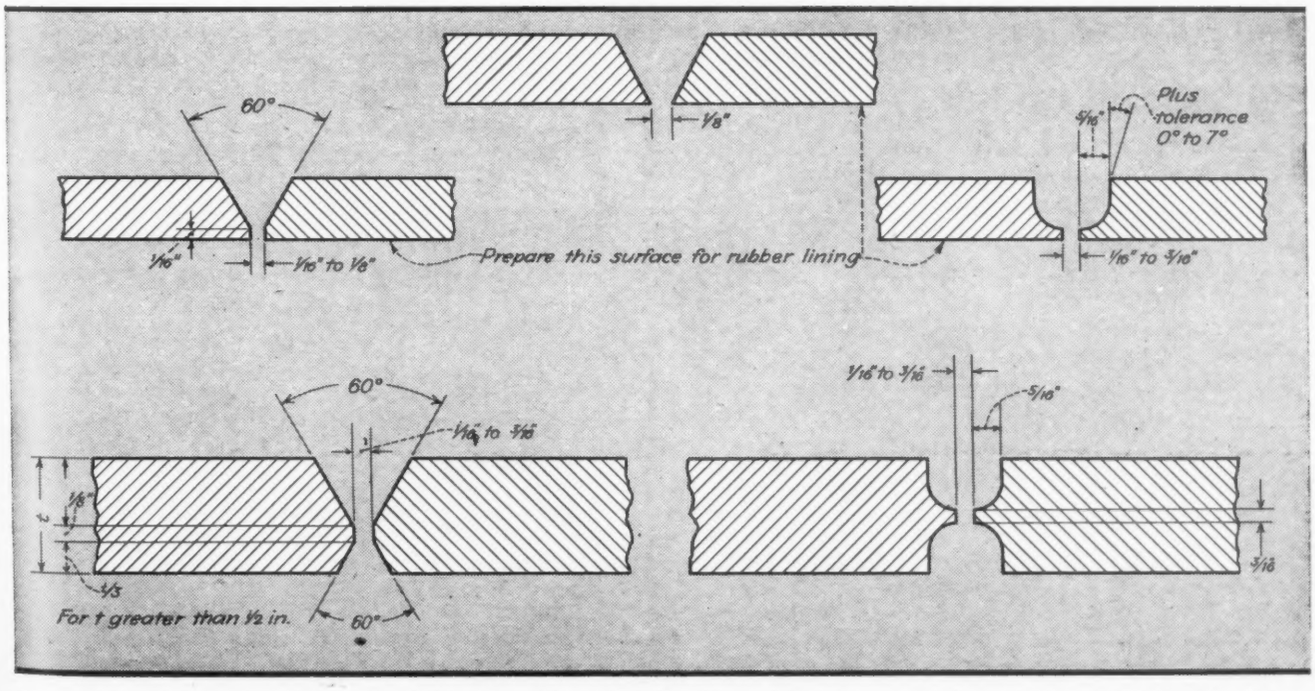


Fig. 2—V- or U-type butt weld is suitable for rubber covering if weld bead is ground smooth and flush with plates.

be smooth with no porosity, holes, high spots, lumps or pockets. Peening can be used to eliminate porosity; grinding the weld bead with a No. 24 grain, grade Q, grinding wheel or finer, is essential to make the weld surfaces smooth enough for covering. A fillet radius of at least 1/4 in. is desirable so that the designation of the weld bead on the drawing, wherever possible, should be built up before grinding to this minimum radius.

In depositing the weld metal, a satisfactory method is first to place layers one and two, Fig. 3(B). Next the V-notch is cleaned carefully, with a chipping tool, down to sound metal, after which weld layers three and four can be deposited. Then layers five and six are deposited to complete the weld. Finally the protruding portions of layers three and four are chipped or ground off to obtain a smooth, flush surface suitable for rubber covering.

Pits, gouges and other surface defects can be filled with weld metal, if necessary, and then ground flush with the plate surface to obtain a satisfactory foundation for the rubber covering. Partitions, braces, supports or other attachments on the inside of a tank should be flush against the adjacent surface and welded along all edges and sides. Spot welding is not permissible. Lap type joints are considered undesirable for welded construction.

Riveted joints can be covered whenever a welded construction is impossible. Countersunk rivets, with the head ground smooth after riveting, are preferable. The cost of rubber coating a smooth surface is less than the cost of coating an equal area studded with rivets because multiple layers of rubber are not required. The smooth surface greatly simplifies the application and vulcanizing of the rubber, thereby resulting in a lower labor cost. These advantages offset the added cost of countersinking the rivets.

All sharp corners must be rounded. A radius of 1/8 in. is about the minimum. Steel surfaces to be rubber covered must be free of grease, weld spatter and all foreign matter. Immediately prior to rubber lining the surfaces are shot-blasted to make them bright and clean.

Surfaces to be rubber covered can be dimensioned to the nearest 1/8 in. A tolerance of plus or minus 1/8 in. is permissible on dimensions of 24 in. or less. For dimensions greater than 24 in. a tolerance of 1/4 in. is permissible. The same tolerance can be applied to over-all dimensions.

Accessibility for preparing the joints and for application of the rubber should not be disregarded in designing manholes, domes and other openings to closed vessels. A good guide in design is to make provision that every square inch of area to be covered is within reach of the hands. This means that some closed vessels, as normally designed for use without linings, will need to be designed with manholes to permit application of the rubber linings. An opening of 18 in. inside diameter is the minimum.

Outlets on rubber lined tanks and vessels, excepting the rare designs in which small openings are made for attaching pressure gages, gage glasses and like appurtenances, are designed for flanged pipe and fittings. Fig. 4 shows welded construction suitable for attaching standard flanges to tanks. Section AA is the easier to line, having fewer changes in contour. This construction is used at any place on the tank, particularly at the bottom to insure drainage.

Although Section BB is not as readily rubber lined, it is better suited to reinforcement than Section AA. Accordingly it is used particularly for manholes, domes and large openings. Because the protruding portion of Section BB on the inside surface would obstruct drainage, this construction is undesirable for openings on the bottom of a vessel.

Flanged pipe and fittings are always used for lining with rubber. Flanges can be either screwed onto the pipe or fillet welded to it. Screwed flanges must be assembled without oil or lubricant since oil attacks rubber. The end of the pipe can be finished flush with the flange after assembly. Weld beads must be ground smooth. If the rubber lining is to go over the end of the pipe so as to cover part of the flange, the inside edge of the pipe should be turned or ground to a 1/4 in. radius, Fig. 5. All oil, grease or other viscous coating must be removed before the rubber is applied.

Following shot-blasting, steel surfaces to be rubber lined are cemented with two coats of primer and one coat of intermediate cement. The rubber, which is cut to convenient size and shape before hand, is treated with naphtha or other reagent to make it tacky just prior to applying it to the cemented surface. Every

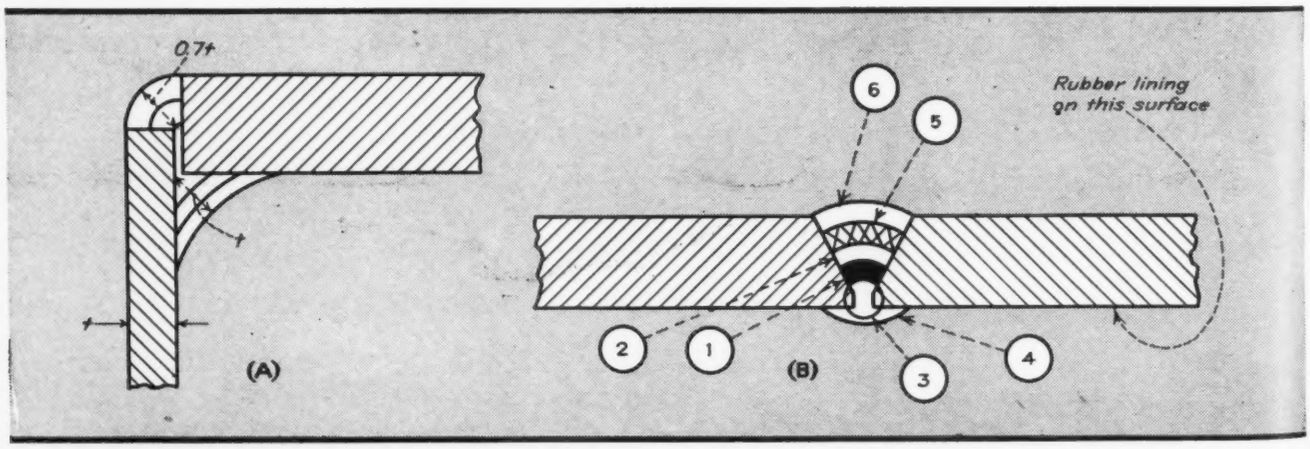


Fig. 3—(A) Suitable proportions for fillet welds. (B) To insure sound weld metal underneath the lining, the notch should be chipped out and filled with weld metal from the inside and then ground flush with the plates.

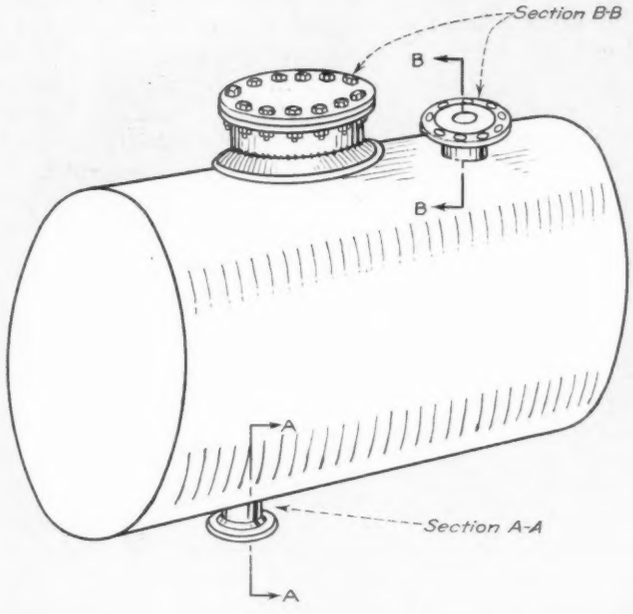


FIG. 4

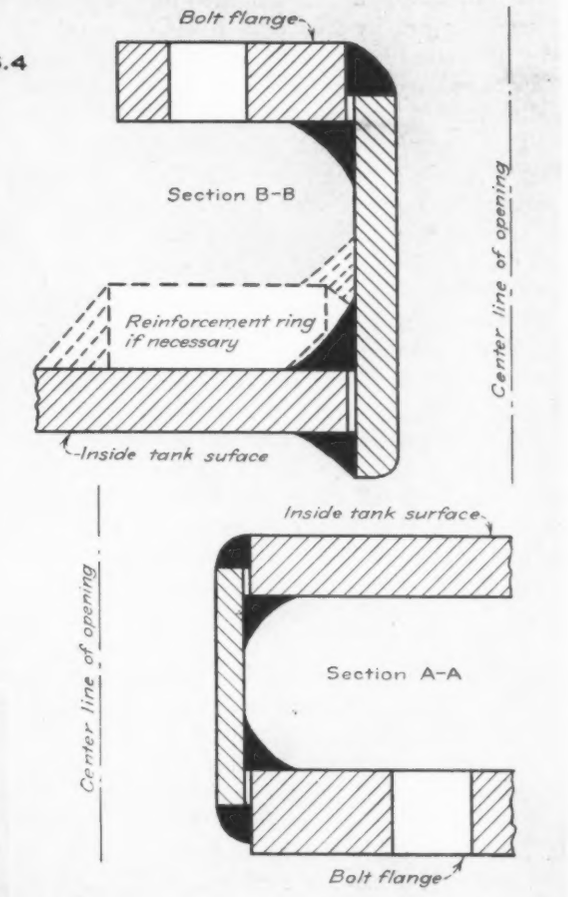


Fig. 4—Openings in tanks and closed vessels are generally adapted for connection to standard flanged pipe and fittings.

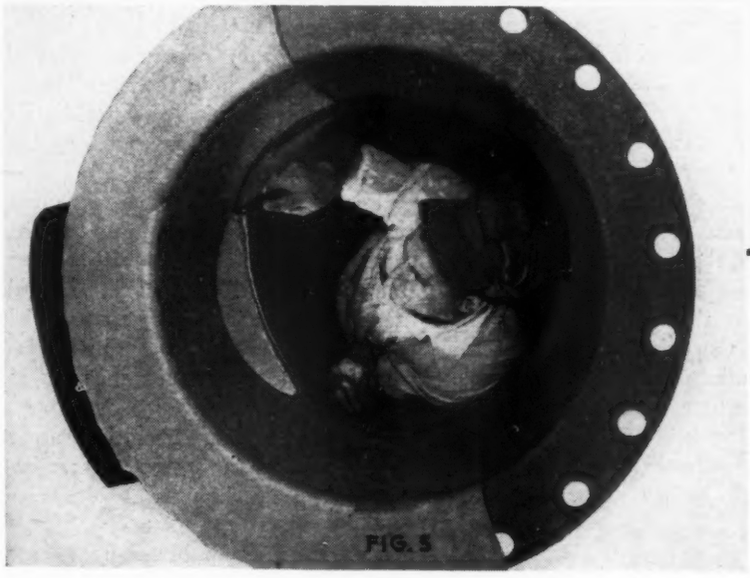


Fig. 5—Rubber lining, 3/16 in. thick, being stitched in place on the inside of large flanged pipe as protection against corrosion from acid.

square inch of the rubber is carefully rolled down usually by hand to force out entrapped air between the rubber and the metal.

Detail of operating pressures or degree of vacuum, whether indoors or outdoors service is contemplated, temperature range and chemical analysis of fluids to be handled are important to the rubber manufacturer in preparing the lining for any given installation. Rubbers are compounded to provide corrosion resistance, resistance to abrasion, high dielectric strength or noncontaminative qualities, depending on which property is needed most. Thus the design should state the kind of service to which the lining is to be subjected so that the lining manufacturer can supply linings best suited to operating conditions.

After the rubber has been applied to the steel, it is cured in place by exhaust or pressure steam depending upon the curing characteristics of rubber stock. After vulcanizing, edges are trimmed and beveled, bolt holes in flanges are cleaned and openings in tanks, such as manholes and threaded holes for pressure gages and gage glasses, are cleaned and finished. Surfaces not rubber covered are painted with acid resistant paint.

Lining thickness of 3/16 in. is standard for tanks and large diameter pipe. Lining thickness of 1/8 in. is standard for small diameter pipe. Thicker linings are used for severe service conditions or to provide additional protection against mechanical abuse.

Typical Applications

Storage tanks of all shapes, sizes and varieties have been rubber lined. Common types are the horizontal cylindrical closed tank and the vertical cylindrical type either open at the top or with cover. The horizontal

closed tanks are usually provided with dished heads and may be designed for pressure or gravity discharge, depending upon the detail of construction. Capacities vary from 2,000 to 50,000 gallons.

This type of tank has many advantages. It is applicable to pressure discharge; its ratio of area to volume is satisfactory; it is economical; it is totally inclosed; it is easy to transport, to handle and to install; it is easy to support and all exterior surfaces are readily accessible for inspection and maintenance. Standard dished heads are readily available under ordinary circumstances. All fabricators are equipped to roll the required longitudinal sections and prompt deliveries can ordinarily be obtained. Particularly in sizes of from 10,000 to 50,000 gallon capacity, this type of tank is most desirable.

The vertical cyclindrical tank generally has a flat bottom and the cover, if any, is quite often of the flat removable type. Although the flat bottom construction is not suitable for pressure, the construction is simple and for smaller sizes, up to 10,000 gallons, is probably the least expensive. Vertical tanks are readily handled, transported and installed. A concrete slab makes a good support. In large diameters the problem of providing covers becomes complicated. To span the large diameter requires a dome shaped cover and considerable expense for structural supports. As a result of these structural limitations, few large size vertical cylindrical tanks are handled at the factory, although field installations for tanks 20 x 20 ft., 30 x 30 ft. and 40 x 40 ft. are not uncommon.

Rubber lined process tanks have become pretty much standard equipment. In this category plating tanks are important. For this service rubber has three important characteristics: First, most plating is done from an acid solution. The rubber provides the necessary resistance to chemical corrosion. Second, rubber, being a nonconductor, insulates the operation and prevents current leakage. This is important because if current leakage occurs, production costs go up, but of even more importance is variation that occurs in deposition and quality of the work. Third, rubber prevents metallic contamination such as might readily occur from lead linings.

In addition to these natural advantages there are two other characteristics that must be built into the rubber compound to insure successful operation. First, the compound must not contain constituents that can be leached out by the solution and that would poison the bath, embrittle, discolor or otherwise affect the quality of the plate. Second, the lining must be of uniform density and composition so as to prevent plating through with resultant deposition of metal on the surface of the rubber.

Plating of production items such as automotive radiator grilles, is done in automatic continuous plating units. The articles to be plated are carried through the various baths while being moved on continuous conveyors. The baths themselves are set in proper sequence and the lengths of the individual tanks are designed so that the time of exposure to each bath is adjusted as required by the operation cycle. Many such parts ultimately have a chrome plated finish. The cycle usually consists of an acid pickle, wash, copper strike, wash, bright nickel plate, wash, chrome plate and wash. In other words, the plate is bright nickel on copper and chrome on bright nickel, that is, the procedure used in the production of all high grade chrome plate.

Rubber lined tanks are used for the pickle, for the bright nickel and for the wash tanks. Rubber is not suitable for the chrome tank. The bright nickel plating is the time consuming operation; hence that tank is the biggest tank for which rubber lining is well suited.

PICKLING TANKS. The tanks for the pickling baths in which steel plate, strip, rod and wire are immersed following processing hot to remove scale and rust can be rubber lined. Since pickling is done at temperatures as high as 235 deg. F. the service is severe. Mechanical abuse is also likely.

While various materials have been used in the construction of pickling tanks, rubber lined tanks are now considered to be the most satisfactory. They have become pretty generally standard equipment. Because of the severity of the service, the steel tanks are necessarily of rugged construction. Rubber lining $\frac{1}{4}$ in. thickness, further protected by inner linings of acid proof brick and cement are used.

Steel strip is ordinarily pickled continuously, the strip being drawn through a series of four or five acid tanks, each approximately 60 ft. long, and thence through hot water and cold water wash tanks, each approximately 30 ft. long. In addition to the tanks, the unit uses rubber lined sectional covers, rubber lined exhaust systems, including ducts, dampers, scrubbers, fans and stacks and a waste acid system including piping and sewer.

Rod and wire are ordinarily pickled in coils by the bath system, the individual tanks being smaller and open at the top to facilitate loading and unloading. Heavy plate is also pickled by batch process in open-topped tanks of size and depth to suit the size of the plate being handled. Automobile rim steel is pickled prior to fabrication and the same applies to disk wheels. Sheet steel for refrigerators, stoves and similar application is pickled prior to enameling. Ships plates are pickled prior to forming. In the tin plate industry, plate is pickled immediately prior to tinning. The same applies to galvanizing.

There are also numerous other types of process tanks for holding corrosive solutions for which rubber linings are suitable and in general use. The Rayon industry uses special rubber lined wash tanks. This equipment is used for washing the spooled yarn. The tanks are essentially open top tanks with false bottoms operating under vacuum, the unit of course being specifically designed for the intended service.

Chlorination and bleach tanks are used in the pulp and paper industry. These are usually vertical cylindrical tanks approximately 15 ft. in diameter by 60 ft. high, equipped with mechanical agitator equipment. Certain types of filters frequently use rubber lined tanks. Zeolite tanks used in industrial water softening are rubber lined for services where it is essential to prevent iron contamination. Crystallizing tanks are used for separation of crystals from mother liquor. Mixing tanks are used for addition of acids to various materials. In such installations if commercial 66 Baume sulphuric acid is used, it should be borne in mind that this acid has a high specific gravity and tends to stratify and settle to the bottom of the tank.

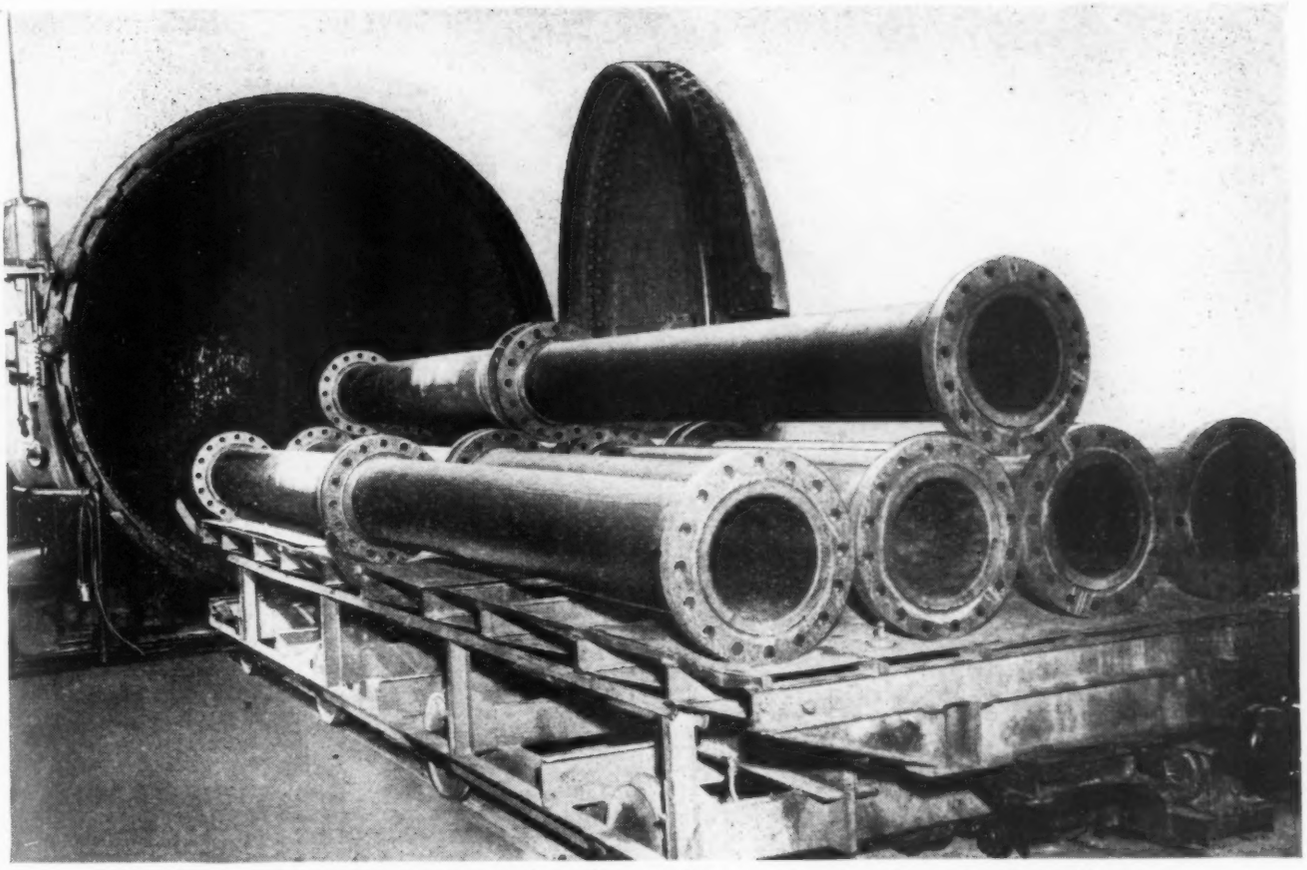


Fig. 6—Rubber-lined pipes ready to be rolled into a vulcanizer for curing the rubber.

Strong sulphuric acid is destructive to rubber; hence, stratification must be prevented by air agitation.

PIPE AND FITTINGS. Rubber lined pipe and fittings are in general use for handling corrosive industrial solutions. For rubber lining, flanged pipe and fittings are used. Rubber lining can be installed in any of the standard flanged fittings and in pipe sections up to 20 foot lengths. In addition, special fabricators, headers, manifolds, bends, and other fittings lend themselves to the rubber lining process. Either flanged fittings of cast iron, which are ordinarily used, or flanged fittings of steel can be covered. Piping fabricated by butt welding should be selected with even edges on the inside. Cast fittings should be selected on a basis of freedom from porosity, cold shuts and other inside surface defects.

The inner edges of all flanges should be ground to at least $\frac{1}{8}$ in. medium radius. It is also necessary in make-up of piping that bolt holes be aligned and that flanged faces be refinished after assembly.

From the point of view of engineering and installation, the problems of most rubber-lined installations will be found closely to parallel the problems encountered with standard steel pipe. For extreme service conditions it should be borne in mind that the rubber lining has definite physical strength limitations and that these limitations are below the corresponding limitations for metal. This means that in making the installation the tension on the bolts must not be such as to introduce a stress beyond the strength limits of the rubber lining. The layout and service conditions must be such that these same limitations are not exceeded as the consequence of stress introduced by expansion and contraction. From a practical standpoint, these limitations cause concern only for larger diameter pipe, higher operating temperatures, extreme temperature differentials, and long lines.

Installation of rubber lined piping must be made with reasonable care. The bolts should be tightened gradually in rotation so as to avoid localized stress, and bolt pressure should not exceed that required to maintain a tight line at the operating pressure. After installation the line should be tested at operating pressure, tightening only those joints that leak. After 28 to 48 hours, the entire line should be gone over again to make certain that all bolts are properly set up. With these simple directions and ordinary care, no trouble should be experienced with ordinary installations.

Insofar as valves are concerned, there are three types of rubber lined valves in common use. A prevalent type is the diaphragm valve. Other common types are the ordinary gate valve and a special design of angle valve, plus certain types of installation for which check valves are required.

For the bulk transportation of acids, bleach and other chemicals, rubber lined tank trucks and rubber lined tank cars are in general use. In tank cars the lining must conform to a specification as drawn up by the Interstate Commerce Commission. A certificate must be furnished the owner to the effect that the car in question has been rubber lined in a manner to conform to the I.C.C. specification. For many years all rubber lined tank cars were of riveted construction. In recent years, the specification has been extended to in-

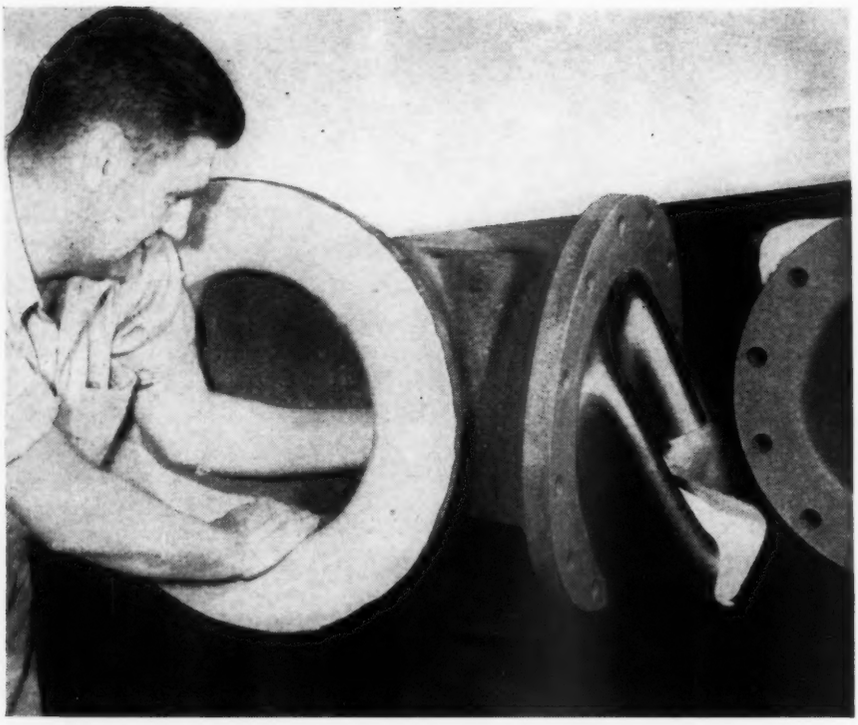


Fig. 7—Layer of 3/16 in. rubber being placed in a large flanged fitting.

clude welded cars, the latter, of course, being much simpler to line as the necessity of applying the rubber over the multiplicity of individual rivet heads is avoided.

Users of rubber lined cars should inspect them frequently. Most of the time the cars are beyond the jurisdiction of the owners and they are subject to damage through indiscriminate methods of sampling, measuring, and unloading. Sometimes sampling bottles are dropped into cars, measuring sticks with sharp ends are used, or cars are unduly heated to facilitate unloading of materials that have a tendency to coagulate such as ferric chloride. Frequent and proper inspection will enable such damage to be repaired before serious damage is done, whereas if damage of this nature is not corrected, loss of load with serious damage to the car or other property is liable to result. The usual tank car is of 8,000 gallon capacity.

There are numerous types of special process equipment for which rubber linings and coverings are adaptable. Generally such equipment is the particular design of the equipment manufacturer. Subsequent to rubber lining or covering the parts are returned to the equipment manufacturer for assembly and for such machining or finishing as may be necessary.

Included among such special rubber covered equipment are continuous washers or filters, which are in common use in the paper industry, the mining industry and the sewage disposal field. The use of continuous filters is being extended into other industries as well. Of course not all filtering operations handle corrosive solutions, so that only a portion of the continuous filters used in industry are rubber lined and covered.

Another type of rubber covered process equipment in general use is exhaust fans. Many types or designs of fans in common use today lend themselves to rubber covering, although the manufacturers must make some modification in design to accommodate the rubber. Top speed must be limited to about 10,000 ft. per min. Also, fans have to be dynamically balanced subsequent to rubber covering. Special rubber pads are applied to the back of the blades to permit such balancing. Usual practice is to return the fans to the manufacturers for dynamic balancing.

Some companies make the manufacture of rubber lined evaporators or crystallizers a specialty. An evaporator is essentially a large tank with a conical bottom, although there are details of design such as baffles, overflow piping, and other apertures to complicate the installation of the rubber. Such equipment operates under vacuum and in many processes under elevated temperature so that the conditions are severe for rubber lining.

Rubber lined centrifugal pumps are also in common use. Here again the design corresponds essentially to the design of an all metal pump, with the exception that the design must allow clearances for rubber subsequent to lining. Rubber lined centrifugal pumps are not suitable for all types of operations as solutions or slurries being handled must be free from sticks, stones and similar foreign matter.

Rubber lined absorption towers are an example of special process equipment. Such towers are commonly used for the counter-current absorption of gases and are ordinarily packed with wooden chips, coke, tile or other material to increase the absorption area. Many towers are divided into sections with perforated partitions, which act as support for the packing. Water, which constantly wets the lining, acts as a protective coating to the rubber thereby enabling the lining to resist gases that ordinarily might be considered as unsuitable for contact with rubber lining. Equipment of similar design is also sometimes used under vacuum to eliminate air or gases from water or other solutions.

Agitators of innumerable sizes and designs are often rubber covered. They vary from small high speed agitators to large slow speed agitators and from one piece to multiple section designs. Multiple sections are held together either by stainless steel bolts or by rubber covered bolts. The latter procedure is preferable because the rubber covering of assembly bolts gives protection against corrosion.

* * * *

In 1838, Pelouze, of France, soaked some cotton in nitric acid and after washing and drying it, found that while it looked just the same as it did before it was treated, it was considerably heavier; that it burned without leaving any ash, and when ignited, whether wet or dry, exploded if given a suitable shock. This experiment led to the later development of gun cotton by Schonbein of Switzerland.

TECHNICAL NEWS HIGHLIGHTS

Particle Accelerators

Atom-Smashers Graduate from Laboratory As Commercial Machine Is Revealed

RECENT UNVEILING of a 20-million volt betatron by the Allis-Chalmers Manufacturing Company as a commercial inspection unit has demonstrated that particle accelerators, popularly known as "atom-smashers" are no longer laboratory curiosities, but standard research and inspection tools. The betatron, which produces X-rays that show up almost microscopic flaws in 20-inch steel sections, was shown at the Picatinny Arsenal, Dover, N. J. This machine and an identical one installed by Allis-Chalmers at the Rock Island Arsenal are the first commercial betatron units. The General Electric Company, in whose laboratories the betatron was invented by D. W. Kerst (now Professor of Physics at the University of Illinois), holds the basic patents on the betatron and has issued a manufacturing license to the Allis-Chalmers Company. A 100-million volt machine developed by General Electric has recently been made available for licensing.

The Betatron

The betatron accelerates only the lighter parts of the atom—the electrons. In this device, a pulse of electrons is turned loose inside a "doughnut" or ring-shaped glass tube, supported between the poles of a large electromagnet.

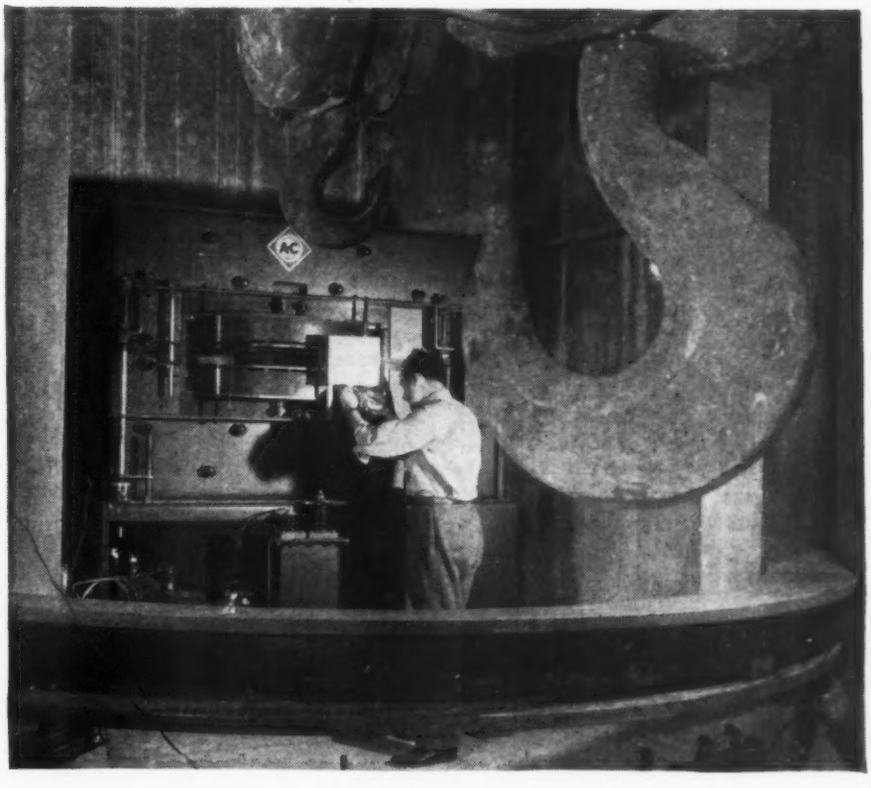
The betatron operates on principles similar to that of alternating-current transformer. In the betatron, the secondary coil is replaced by the "doughnut"—essentially a vacuum tube. The electrons originate from a heated filament, and instead of traveling through a wire, flow in open space, held in their orbit by the huge electromagnet.

If the electrons remained in the tube continually, they would first revolve one way, then stop and reverse, but the trick is to get them out while they are moving at maximum energy. The current builds up from zero to its maximum voltage in the first quarter cycle; before the electrons go into reverse and lose energy, they are shifted from their orbit, and made to hit a tungsten target, generating a beam of high-voltage X-rays.

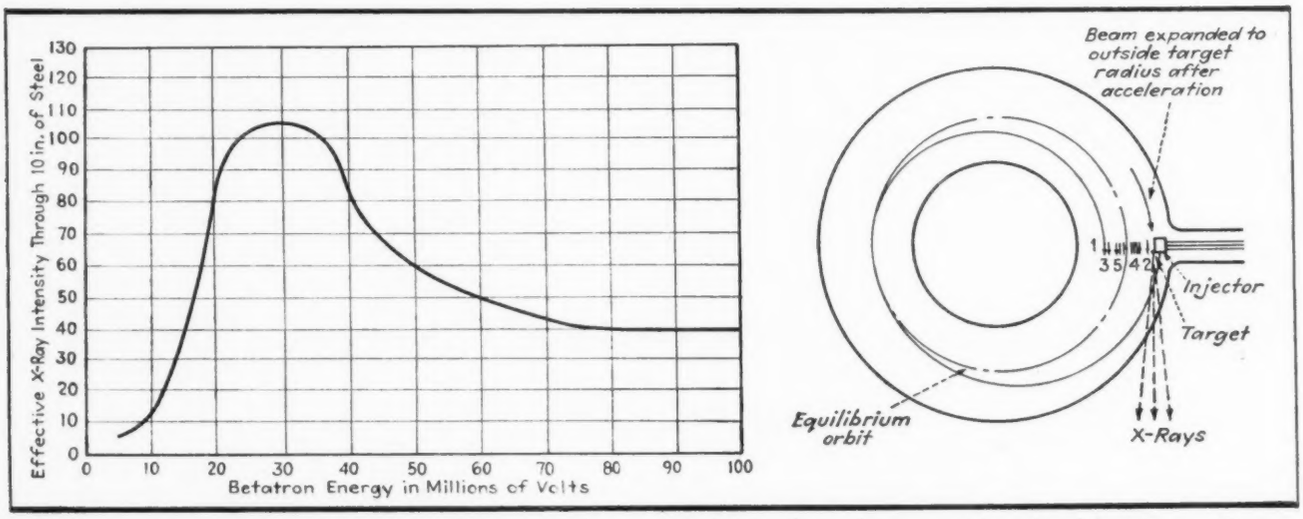
The 20 million volt betatron operates with a current alternating at a frequency of 180 cycles per sec. The electrons are accelerated in 1/720 sec., that is, a quarter-cycle of each alternation. During that time, they spin around 350,000 times in the vacuum tube and travel a total distance of 250 miles, reaching a velocity of 186,000 miles per sec., just a fraction of one percent below the speed of light. By Einstein's law, the electron increases its mass forty-fold thereby increasing the potential to do damage.

The 100-million volt betatron was designed by G. E. using the "d.c. bias" method. In addition to the alternating current, a direct current can be applied to the electromagnet. This shifts the zero line from the middle of the current wave to its bottom, and nearly the whole of the rise can be utilized. Using this method, even higher energies can be developed, and a 250-million volt machine is being planned at the University of Illinois.

Conventional methods of producing



Installation of 20-million volt betatron at Picatinny Arsenal. The magnet cubicle is surrounded by a 15-foot rotating ring, for inspecting shells ten inches and smaller. For bulky objects the overhead crane is used. Square object in center is ionization chamber, which measures X-ray intensity directly in "r" or Roentgen units.



(Left) Maximum energy for production of X-rays in betatron. Higher-energy machines are being developed, but beam of electrons will be utilized directly.

(Right) Looking down on "donut" of betatron. Successive electron paths approach equilibrium orbit near center. Tungsten target is mounted on electron gun.

X-rays make use of a high potential difference between the electron source and the target. Electrons attracted to the target strike it to produce X-rays of energy equivalent to the force to which the electrons have been accelerated. Because of problems of insulation at high potentials, the maximum practicable energy achieved by this method is in the neighborhood of 4 million volts. The betatron installation at Picatinny reliably yields 100 r (Roentgen units) per minute at three feet. At this intensity the protection necessary for the operating personnel consists of only 20 in. of concrete completely inclosing the magnet and X-ray room, with the exception of the wall in the direct path of the X-ray beam—at a distance of 40 ft. from the betatron five feet of concrete is necessary.

Use of more powerful X-rays for radiographic inspection has been accepted by industry. But creating stronger energy sources does not always mean more powerful X-rays. The accompanying graph shows the limiting energy that produces the maximum intensity of X-rays. However, more powerful betatrons are being built, because it is planned to use the beam of electrons itself, not the X-rays. In high-energy machines like the betatron, the electron beam is quite sharp. It is predicted that 250-million volt electron beams will be useful in medicine as well as in industry.

The Synchrotron

The newest of the particle accelerators is the synchrotron. Invented independently by a Russian physicist and by Dr. E. M. MacMillan, of the University of California, construction of synchrotrons is now under way at the University of California and at the General Electric Research Laboratory in Schenectady, N. Y.

Essentially, the synchrotron is an application of the cyclotron to the betatron. In the cyclotron, particles are led into a hollow, split copper drum incased in the tank between holes of the magnet. Each time it goes across the gap between the half-drums (known as "dees"), it receives a strong electrical pulse, the circle widening with each pulse until the particle emerges from a slit at the side. The time for the particle to make the big circles is the same as for the small ones, the increasing speed exactly compensating for the greater distance traveled. The frequency of the alternating current that gives the particle its push is spaced so that the pulse always comes at the moment the particle is in the gap.

The theory of relativity, however, predicts that particles will eventually become heavier as their energy is increased. The increased weight results in a tendency of the particles to lag, and arrive at the gap too late to be pushed. When the weight increase has become appreciable the particles will tend to fall out of step with the regularly spaced electrical pushes, and no further acceleration is accomplished.

In the synchrotron this effect will be overcome by changing the magnetic field to compensate for the slowing down as the particle becomes heavier. As the energy of the particle increases, the magnetic field of the synchrotron is increased, jerking the lagging projectile up to the point where it will receive a push at the exact time of the pulse.

The synchrotron will borrow the cyclotron idea of repeated acceleration in a circular path. However, the characteristics of the particles it will accelerate—electrons—dictate differences in detail of construction and operation.

Because it is so light, the increase in mass as the electron gains energy is proportionately huge, and appears at relatively low energies. At 300 million electron-volts, an electron weighs 600 times as much as it does at rest. One result of the rapid increase in weight of the electron is that the orbit of the circle it travels does not increase with energy but tends to remain in a perfectly circular path. Therefore, the synchrotron accelerating tank will be doughnut shaped.

In the synchrotron now being built at the University of California this limitation will become effective at 300 million electron-volts. The doughnut shaped magnet, to be made of laminated transformer steel, will weigh 135 tons. The orbit in the acceleration tank between the poles will be one meter. Professor McMillan estimates that with a magnet and an orbit about three times this size it may be possible to accelerate electrons to one billion electron-volts. The General Electric synchrotron, being built under a contract with the Office of Naval Research, is a betatron in which the electrons traveling around the "doughnut" get additional pushes from electrical oscillations of a shortwave transmitter.

The Cyclotron

One of the earliest atom-smashers is the cyclotron, invented in 1930 by Dr. E. O. Lawrence of the University of

California. In this device, protons, deuterons and other "heavy" atomic particles are accelerated to high velocity by sending them in an expanding spiral path and giving them a carefully timed pulse or kick twice each revolution, using a magnetic field to speed up the particles.

Energies up to 10 million electron-volts were obtained in prewar cyclotrons, and Dr. Lawrence had, early in the war, a giant one under way. The huge magnet of this machine was converted to an "atom sorter," to separate uranium isotopes, in the atomic bomb project.

Last month, Dr. Lawrence unveiled his new 4,000-ton cyclotron at the University of California. Two days after its completion, the machine was accelerating deuterons ("heavy" hydrogen particles) to an energy of 200-million electron-volts. The 184-inch machine is the same one that was started in 1940.

With 200 and 300 million electron-volt energies, atom-smashing will mount a new threshold. It may be possible, instead of splitting the nucleus, to split particles of the nucleus, such as protons and neutrons.

With particles of these energies it will be possible to study the cosmic rays, or mesotrons. A 300 million electron-volt electron is itself a cosmic ray particle, and such a particle will produce cosmic ray showers, such as occur in nature, of equal energy. An understanding of the mesotrons is considered to be of the utmost importance in learning about fundamental nuclear forces. Mesotrons, which constantly bombard the earth at energies up to billions of electron volts, can be studied at present only on nature's terms.

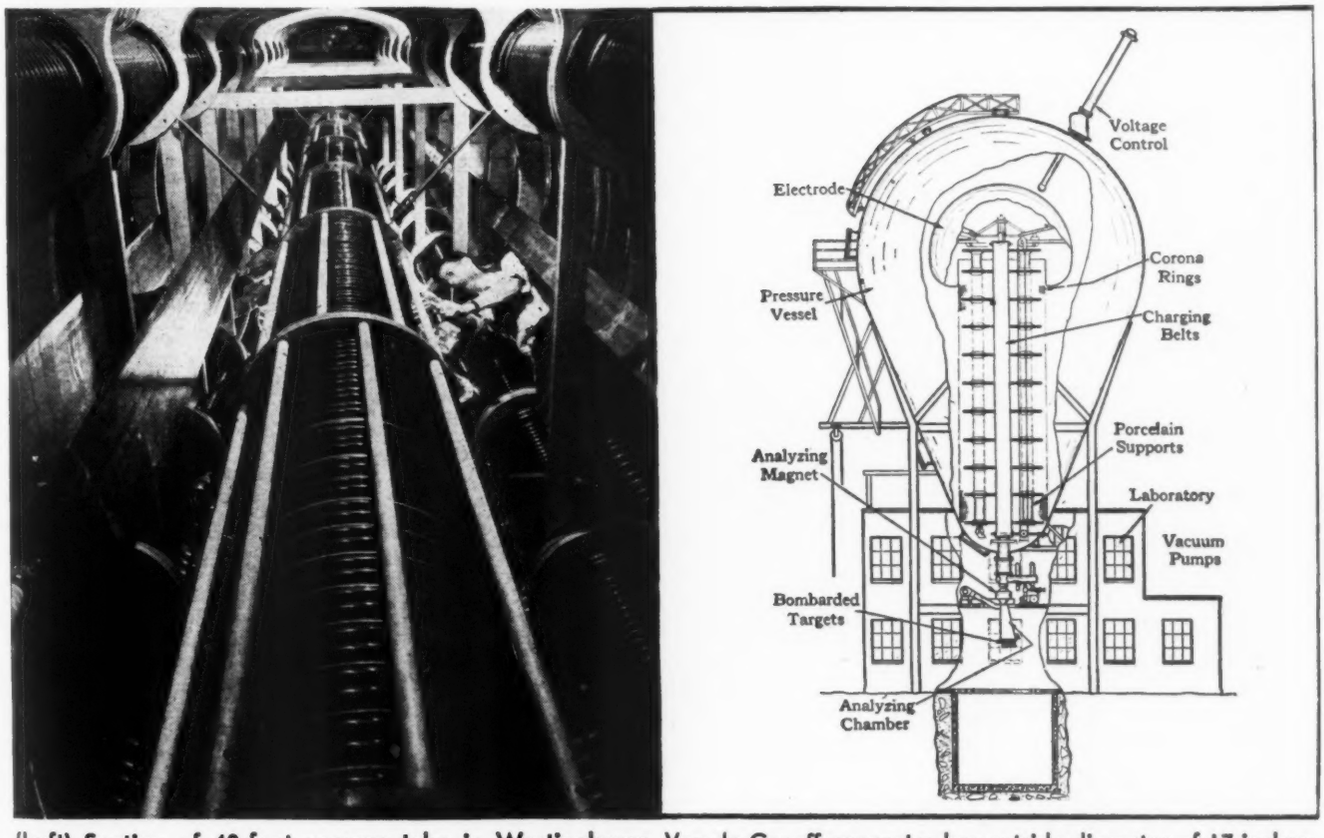
Van de Graaff Generator

Another early particle accelerator, and one which is in active use, is the Van de Graaff generator, named for its inventor, R. J. Van de Graaff, of the Massachusetts Institute of Technology. This is called the pressure electrostatic or belt-type of generator.

This machine consists essentially of a large, pear-shaped steel tank, containing air under pressure—anywhere from 60 to 120 lb. per sq. in. Raising the pressure increases the obtainable voltage, because it increases the dielectric strength of the insulating air. Electric charge is carried from a generator at the base of the tank by two belts running up to the electrode, which is a big metal semi-sphere. The charge accumulates on its outer surface, creating a high potential between electrode and ground. In the electrode an arc discharge of hydrogen is maintained. This produces hydrogen ions—hydrogen atoms minus their planetary electrons — and deuterons — double hydrogen atoms, minus their electrons. The high voltage built up in the electrode propels the ions down a 40-foot-long vacuum tube, into the material being studied. (See accompanying illustrations.) Directed at the targets at the bottom of the tube, the ions are accelerated en route by the electrical field created by the high voltage.

The important feature of the Van de Graaff machine is not the high voltage, however, but rather its steadiness. A series of plates, located at regular intervals along the length of the tube, carry the electrical field, and cause all the "bullets" to move at the same speed at any one point in the path. Because of its ability to get from zero to four million volts with an accuracy of 1/10 of 1 percent, studies of high precision can be made.

Although present applications of this machine lie in the fields of medicine and biology, through the production of radioactive isotopes, indications are that this research will lead to more economical generation of electric power.



(Left) Section of 40-foot vacuum tube in Westinghouse Van de Graaff generator has outside diameter of 17 inches. (Right) Diagram of steel "pear" on pressure tank. Electric charge is hurled down through tube, striking target.

World's Largest Reciprocating Aircraft Engine

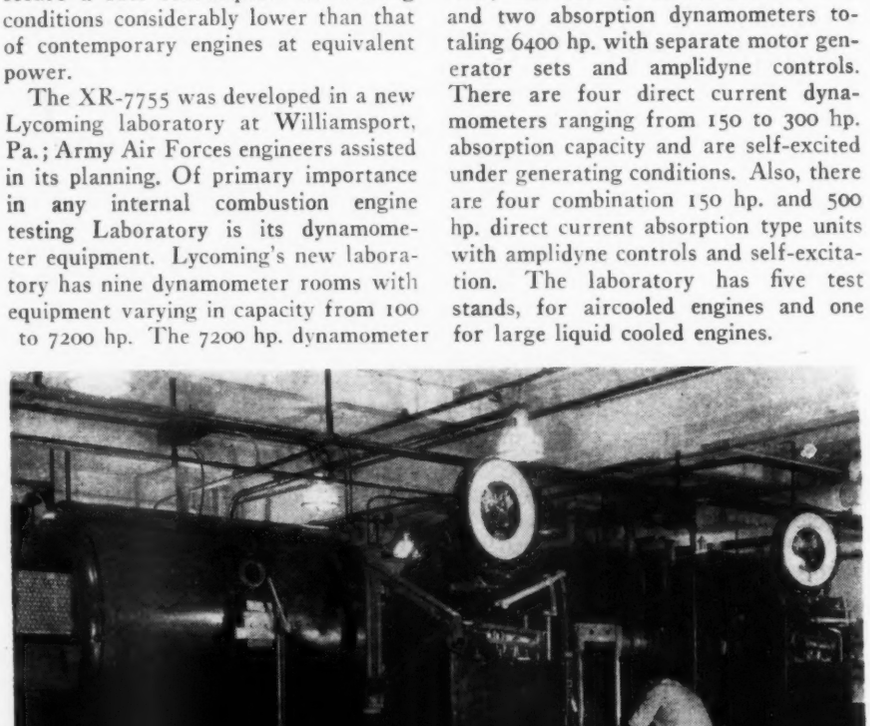
MOST POWERFUL RECIPROCATING aircraft power plant in the world today, the Army Air Forces model XR-7755 has been built by the Lycoming Division of the Aviation Corporation. It develops 5000 hp. at 2600 r.p.m. for take off and 4000 hp. at 2300 r.p.m. for continuous operation. In construction, the engine is a 36 cylinder, single crankshaft, liquid cooled, radial type with cylinders arranged in four rows of nine each and having a total piston displacement of 7755 cu. in. A few of the accessories are mounted conventionally at the rear of the engine, but the two starters, tachometers, and propeller governor, as well as the low tension magnetos and distributors, are located ahead of the front row of cylinders.

The engine, slightly over 10 ft. long and 5 ft. in diameter, weighing 6050 lb., produces more power than the average railway locomotive. A modern steam locomotive of equivalent power is 90 ft. long, 15 ft. high, weighing 670,000 pounds.

Being liquid cooled, it is necessary that this engine have a pump to circulate the coolant through the labyrinth of passages to carry away the vast amount of heat dissipated through cylinder heads and walls. While operating at take-off speed and power, this heat dissipation amounts to approximately 95,600 B.t.u. per min. (2250 hp.), requiring that the pump circulate the coolant at a rate of 750 g.p.m. The oil pressure pump has a capacity of 500 lb. per min., which is equal to 71 g.p.m. at an outlet pressure of over 100 lb. per sq. in. At the maximum power of the engine, this heat rejection is at the rate of 25,500 B.t.u. per min. (600 hp.) Another pump located in the reduction gear unit increases the pressure from 100 to 300 lb. per sq. in. for the operation of the shifting mechanism.

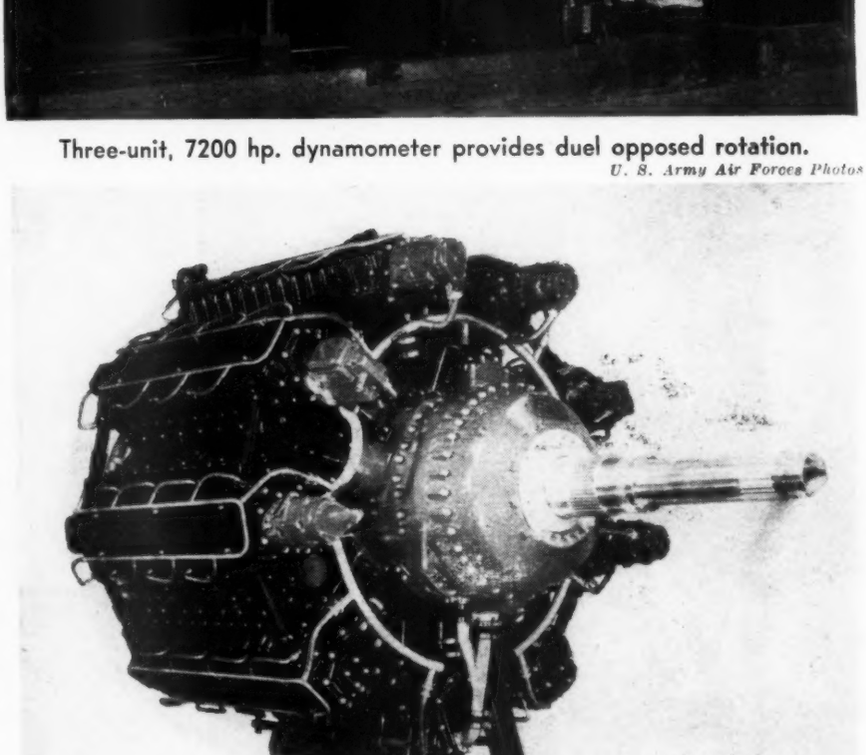
The design of this engine incorporates several unique features. The propeller drive is through a two speed dual rotation reduction gear, either ratio of which can be used at the pilot's discretion to obtain maximum propeller efficiency. The shifting is accomplished hydraulically and provides a direct drive to each of the two propeller shafts without the use of a friction clutch. Another feature is the use of camshafts, with two separate sets of cams that can be shifted to change the valve timing for maximum power or cruising economy. The ignition timing is also adjustable and is operated by the same mechanism that shifts the camshafts. These innovations make it possible to secure a fuel consumption at cruising conditions considerably lower than that of contemporary engines at equivalent power.

The XR-7755 was developed in a new Lycoming laboratory at Williamsport, Pa.; Army Air Forces engineers assisted in its planning. Of primary importance in any internal combustion engine testing Laboratory is its dynamometer equipment. Lycoming's new laboratory has nine dynamometer rooms with equipment varying in capacity from 100 to 7200 hp. The 7200 hp. dynamometer is provided for dual opposed rotation and is composed of three units in tandem; one 800 hp. direct current unit and two absorption dynamometers totaling 6400 hp. with separate motor generator sets and amplidyne controls. There are four direct current dynamometers ranging from 150 to 300 hp. absorption capacity and are self-excited under generating conditions. Also, there are four combination 150 hp. and 500 hp. direct current absorption type units with amplidyne controls and self-excitation. The laboratory has five test stands, for aircooled engines and one for large liquid cooled engines.



Three-unit, 7200 hp. dynamometer provides duel opposed rotation.

U. S. Army Air Forces Photos



Three-quarter front view of the new 5000-hp. Army Air Forces engine.

WASHINGTON NOTES

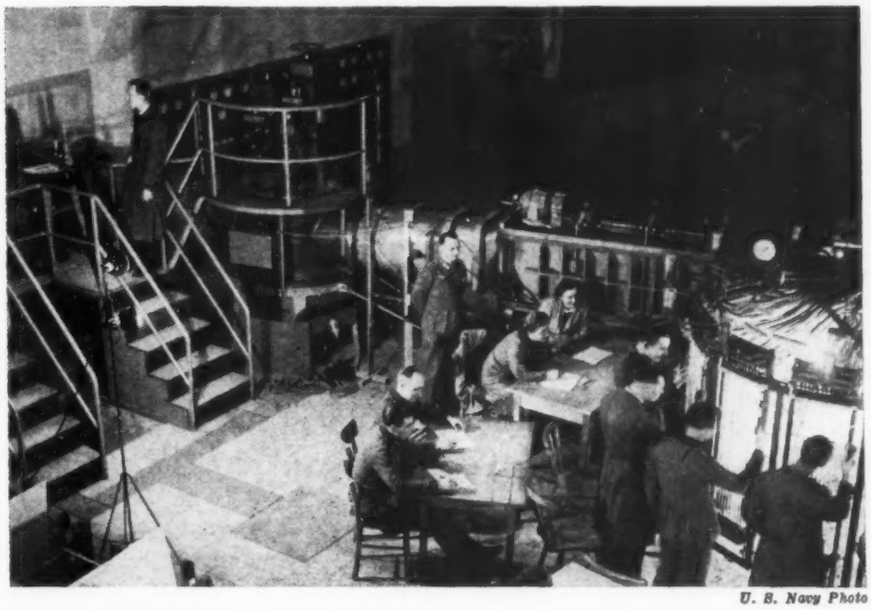
Speculations on New Congress Rife in Washington

Rumors of impending changes in Washington center around what the new House and Senate will do in the 80th Congressional session. Some of the speculation is cautious, but there is a school of thought that believes the changes now evident should not be discounted too greatly, remembering that the new Congress will have ample power to put in effect such laws as it deems appropriate to implement the Republican program.

Investigating War Agencies—One big field of early activity probably is going to be exploring the operations of certain war agencies and controls. The whole story on this subject has never come out, at least not in the light it will show under examination by the new Congress. Surviving war agencies are going to have an increasingly difficult time to maintain controls. If not abolished, it is felt that their scope will be materially altered by reduced appropriations.

As to regular departments, they will be subject to the same scrutiny. This puts a brake on their outlook, at least for the immediate future.

Research—This program will probably extend to the Kilgore-Magnuson national research foundation bill, according to observers. They think it impossible that an economy-minded Congress will authorize a new government agency to cost from 30 to 100 million dollars a year, with Army and Navy research programs well under way and performing satisfactorily. How this will affect the study now being made by the President's Scientific Research Board (see December "Washington Notes") under the direction of John R. Steelman is not known. The report, which is expected to be completed within six months, will include studies on personnel, extent of government research programs, costs of such activities, and comparisons with nonfederal research projects.



U. S. Navy Photo

PROVING GROUND FOR THE ROCKET BOMB—Peacefully reposing at the Naval Ordnance Laboratory, Washington, D. C., is the supersonic wind tunnel used by the Nazis for all of their experiments leading to the V-2 Rocket Bomb.

The working room is shown during a typical pressure-measurement experiment. On the right are various German personnel as they read data from the bank of one hundred and twenty manometers. In the upper center of the picture, the large quick-opening valve is shown. This valve when opened, permits the passage of the air through the wind tunnel into the previously evacuated sphere. In about one second, this valve opens a passage 27½ inches in diameter, something of a feat in a valve of this size. The upper left shows a section of the control panel, from which the operator controls automatically the tunnel and its compression machinery, valves and other heavy equipment.

Scientific Personnel Shortage

One of the critical shortages facing this country today is the lack of highly trained scientists and engineers. Industry, universities, and government agencies are all quite aware of the present dearth of trained scientific personnel, but most of these groups hope that peak enrollments at the universities and colleges today will ease the situation within a few years. These hopes for an adequate supply of scientific personnel in the future now appear to be a bit optimistic, since many of the higher ranking students are turning to other professions because of liberal grants and subsidies.

The chief competitors for future college graduates will be the Army and Navy, which are offering attractive subsidies to students who desire to become military officers. The Navy program, having been authorized in the last session of Congress, has been under way since August. The Army and Air Forces also plan to propose similar legislation very early in the next Congress. The Navy program (Halloway Act) provides for the training of 14,000 college students. For the year 1946-47 there are approximately 7,000 or 8,000 candidates.

The regular students who are selected by precollege competitive examinations will receive $600 per year plus tuition fees, textbooks, GI insurance of $10,000, and travel to and from the school. Enrollees will also participate in three summer cruises of six weeks each, all expenses provided. After four years of college, the graduates must serve 15 months on active duty with the Navy or Marine Corps, after which they have the option of entering the regular service or going on inactive duty in the Reserve.

The naval aviation program, which provides similar subsidies to students, will graduate 1,400 naval aviators per year. Another program, which provides minor subsidies, will also require 1,400 reserve officers per year.

The courses of study for these students have no limitations except that 24 semester hours of naval science must be completed by the end of the four years. The contemplated Army program will be similar, with the goal of producing about 30,000 commissioned officers, of which 5,000 or 6,000 will be air force officers.

These combined programs indicate

that approximately 40,000 college seniors will be subsidized by the programs. This number is equivalent to about 40 percent of the total first degrees granted to males by colleges before the war. In view of the attractive subsidies and certain social advantages granted by these programs, many of the ablest youth of the country will be eager to participate in them. These students will then be lost as possible candidates for the scientific fields.

The Navy states that many of these graduates will not enter the regular Navy and will be available for scientific study, but this situation would make science even more dependent on the military. The only alternative in the competition for these able students would be increased scholarship and fellowship programs, attractive enough to compete with the service programs.

German Scientists—The present shortage of trained scientific and technical specialists may be somewhat eased within the next few months by the recently announced joint State, War, and Navy Department policy to bring 1,000 German-Austrian scientists to the United States to aid the Army, Navy and industrial research programs.

At present there are, in this country, more than 250 German scientists who have been brought over since VE-Day to work on military projects. The remainder of the quota will concentrate their efforts exclusively on Army and Navy projects. Some of these scientists, upon completion of their military work, will be made available to industry and educational institutions.

The military agencies, in conjunction with industry and the Department of Commerce, have compiled a list of 1,400 top scientists from which the quota for the United States will be selected. Any interested organization can acquire these scientists by contract arrangements with the Department of Commerce. These scientists will not be released to industry until they acquire the status of immigrants and are eligible to file papers for citizenship.

DISCUSSIONS AND COMMENTS FROM READERS

Experimental Stress Analysis Symposium

EDITOR'S NOTE: Following are a few of the comments that have been received in response to the sixteen-page insert "Experimental Stress Analysis Symposium" which was published in the December issue of PRODUCT ENGINEERING.

To the Editor:

In addition to the direct application of the electrical strain gage to the product itself, as illustrated in your insert, instruments have been developed in which the gage is incorporated as a permanent part. One application of this type is a portable machine for weighing loaded airplanes; one of the units is placed under each wheel, avoiding the use of bulky scales. Another example is the model tester for determining the flexibility of typing systems, illustrated in the November issue of *Power*, page 70, Fig. 3.

A discussion of these instruments might stimulate further development in this direction. —L.C.A.

To the Editor:

Although I am not a specialist in the field, your Experimental Stress Analysis insert has suggested one thought to me: I have encountered several small firms who have not gone into the Experimental Stress Analysis field because they believed that highly trained personnel and expensive equipment were necessary. I would suggest that there be published an outline of what training is necessary, how long is required to get results, what investment is necessary and where information on this subject is to be found. This would be a valuable supplement to your insert.

—MORSE HILL

To the Editor:

Your editors deserve a vote of thanks from the engineering profession for preparing the "Experimental Stress Analysis Symposium" insert.

I would suggest, however, that in the future some of the other types of experimental methods by which stress can be analyzed be included. I refer especially to Prandtl's membrane analogy and Nadai's sand heap analogy for elastic and plastic portion.

—D. H. PLETTA
Professor of Applied Mechanics
Virginia Polytechnic Institute

To the Editor:

Your December insert is extremely valuable. May I suggest the following: It would seem desirable to mention the new tool of investigation known as X-Ray stress analysis. Reference to this method has been made in several publications, such as the following:

Experimental Stress Analysis, Proceedings
vol. I, no. 2, p. 77, 1943
vol. II, no. 1, p. 157, 1944
vol. IV, 1946 (in preparation)

Welding Journal, Research Supplement
vol. 25, p. 269, 1946
vol. 25, p. 729, 1946

—D. Rosenthal
Associate Professor in Engineering
University of California

EDITOR'S NOTE: We thank our readers for these suggestions. Such discussions will appear in the pages of PRODUCT ENGINEERING.

To the Editor:

In connection with your December insert, you might be interested to know that our company is making wide use of stresscoat, the various types of strain gages, recording apparatus and other devices for improving knowledge of operating stresses. In fact, some of our engineers have patented precision strain gages, which are adaptable to special problems not too conveniently met by the conventional SR4 gage.

—L. A. DANSE
Production Engineering Section
General Motors Corporation

To the Editor:

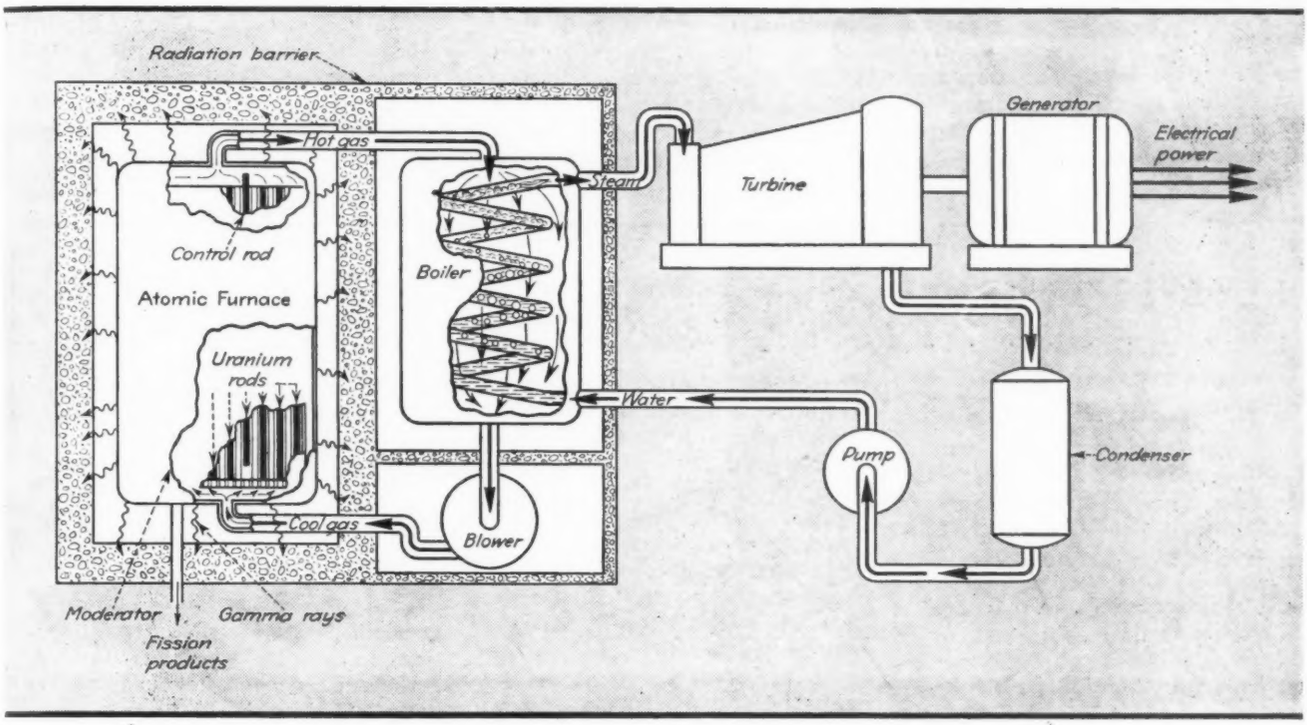
Your stress analysis insert is a fine presentation of the subject. Two ideas occurred to me: Engineers in smaller plants often do not need the careful quantitative type of analysis shown in your insert: they can often evaluate distribution of strains qualitatively by using simple soft rubber models. Perhaps some information on this technique would be useful.

In looking through a book on the mechanics of materials recently, the thought struck me that much of our current theoretical work puts too much faith in the validity of formulas. It is my opinion that we need less numerical analysis and more insight into physical processes. —H. O. FUCHS
Preco, Inc.

To the Editor:

Your stress analysis insert is an excellent idea because it will stimulate the interest of engineers in showing them the power of such methods. As for the material in the insert, I would like to make several criticisms:

In the article on electrical resistance wire strain gages, the engineer is left



Atomic-Electric Power Plant Designed

HARNESSING ATOMIC ENERGY as fuel for an electric power plant has progressed to the release of this schematic diagram showing how the projected Oak Ridge power installation, which the Monsanto Chemical Co. has contracted to build for the Government, will operate. The sketch indicates that the world's first atomic power plant will include all elements of a conventional power central station; namely, the turbine, generator and condenser.

In its initial operation, the unit will use steam for turning the prime mover; the water will be heated in the boiler by an as yet undetermined heat transfer agent, which will serve also as a coolant for the uranium pile. Theoretically it is possible to use ordinary water, heavy water, gases, or liquids other than water as the heat transfer agent and coolant. Several liquid metals are also being studied for this purpose.

The sketch indicates that only the atomic pile-furnace and boiler will need to be shielded in lead and concrete to protect operating workers from radiation. The steam from the boiler apparently is not expected to pick up radioactivity from the heat transfer agent. The amount of shielding required around the boiler unit appears to be only about one-third of that required around the uranium pile.

Manhattan District's report on the status of the power plant states that initial operation of the installation is at least two years in the future. No construction has been started and none of the major components for the station have yet been ordered.

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with no idea as to what such a gage looks like. Further, he should be told that even if the strains in a structure go beyond the yield point, these gages would still tell him what strains are present.

In Dr. Murray's paper on photoelastic stress patterns, it should be stated more clearly that this technique at present will only interpret by analogy the stresses operating in an elastic structure. This method cannot tell what is happening after yield has occurred.

—K. H. SWAINGER
Imperial College of Science and Technology, London, England

To the Editor:

Your stress analysis insert is an extremely clear presentation of the subject and brings home the value of these techniques better than anything I have seen. I would appreciate your sending me several copies of the insert so that I can pass them along to people who would make use of them.

—T. D. GREEN
Hartford-Empire Company

To the Editor:

Your December insert is excellent as as far as it goes, but in my opinion it does not cover the field completely. The absence of electrical strain gages, of which there are several types, was striking; the same can be said of mechanical devices such as Hugenbergers and dial gages.

The first paragraph on the first page of your insert contains the expression "stress distribution and magnitude of stresses." It seems to me that the words "stress distribution" necessarily include the rest of the phrase, since the distribution of stresses is of little use without a knowledge of the stress magnitude. A.J.D.

EDITORS NOTE: Articles on electrical strain gages and other instruments not covered in the insert will be published in future issues of PRODUCT ENGINEERING. As for A.J.D.'s criticism, we do not agree. Distribution is a qualitative factor while magnitude is quantitative.

To the Editor:

I liked your "Experimental Stress Analysis Symposium" very much. I am taking the liberty of making a few suggestions:

A bibliography of references in this subject should have been attached. Also,

I believe that magnaflux-stresscoat was emphasized too much. A survey showing the various methods of stress analysis would have been appreciated. Since the difference between stress and strain is understood only by a few people, I think the difference between them should have been made clear.

I would like to point out that stress analysis can be carried out with very little instrumentation. A few spring scales or weights, perhaps a tensile testing to apply the load, and deflection can be measured by regular dial gages. The stresses can then be easily determined. While working in a large laboratory which had a stresscoat outfit and instrumentation for electrical strain measurement, I was still able to make many analyses by simple means.

—F.M.

Foreign Reports

. . . . . from McGraw-Hill World News

Foreign Engineers Grapple With Shortages

Conversations with delegates to the International Technical Congress held in Paris (see November "Foreign Reports") brought out some interesting sidelights. It was revealed that nations looking forward to rapid industrialization anticipate obtaining initial plant, equipment and power-production units from the U.S., Britain, France, Czechoslovakia, Russia and Italy. None is anticipating that Germany will be permitted to manufacture and export equipment in competition with other industrial nations.

Lack of materials, power and machines and other plant equipment are stalling French automobile production. Therefore, French builders are concentrating on new ideas, and currently are offering extra light-weight cars to domestic and overseas purchasers. To Americans they will seem like oversize mechanical toys. (See story in December "Industry and Societies.")

France is planning heavily on shale oil, synthetic petroleum products, and natural gas—recently discovered in the Pyrenees—for overcoming the shortage of fuel for her industries. Building of synthetic petroleum plants and refineries is to proceed immediately. This is being done simultaneously with reconstruction and modernization of bomb-damaged and sabotaged refineries. Large orders for equipment for this particular industry are being prepared. The combined power and navigation project in the upper and lower Rhone valleys in France is now being pushed to completion. The French Government has also announced that it will now combine the hydro-electric, flood control and irrigation project for the Niger river in French West Africa.

In an official report to the Congress, engineers from Czechoslovakia reported on industry in that country. Principle problems are shortage of raw materials, fuel and power; poor transportation facilities because of the bad condition of railway right-of-way, motive power and rolling stock, as well as the lack of motor transport; bad distribution of industrial plants throughout the country; physical exhaustion of the population and shortage of skilled workers; worn-out plant equipment and machine tools; and many industrial undertakings are without management heads and financial resources. The Czech government is making an inventory of all industrial plants and their equipment. It has planned to offset the deficits in certain industries against surpluses in others, and has fixed manufacturing priorities. Machine tool builders will be permitted to make only certain sizes and types of machines—production being distributed evenly over the group of manufacturers. This is being done to prevent duplication of effort and to conserve materials.

Egyptian industry is planning for expanded production of textiles, building materials, glassware, clothing, cooking utensils, leather products, electrical accessories, ceramic products, and processed food. Hungarian engineers at the Congress reported that their country has planned a hydro-electric project.

Batt Urges Standards Unification at London Meeting

"The time has come for action toward reconciling British and American standards." This was the keynote of an address to the Institute of Mechanical Engineers by William L. Batt, chairman of SKF Industries and former vice-chairman of the War Production Board, at a meeting of the British group in London and by their enthusiastic reception the British engineers showed their agreement with his thesis.

Citing instance after instance where the lack of a common standard of screw-threaded design meant time and money lost from holdups in war production, and infinitely more precious losses of life and danger to freedom, in the recent war, Mr. Batt stressed the need for more rapid progress toward the attaining of that single standard.

The history of the long and slow progress since the first world war toward a common screw thread standard, which Mr. Batt traced in some detail and which is familiar to most engineers, indicates that engineers in both countries possess the two requisites for reaching agreement; a sincere desire to reach it, and an established basis of fact.

Mr. Batt first became concerned in the matter of screw-thread unification as a result of his knowledge of the delays in production as American chairman of the Combined Resources and Production Board. Two previous conferences—one in London and one in Ottawa—which have taken steps toward the unification of screw-thread standards, were held under the auspices of the CRPB. (See story on page 324 of the April 1946 "Industry and Societies").

Following Mr. Batt at the rostrum, Mr. S. J. Harley, head of the British delegation in the Ottawa conference on standards, reviewed the progress which the British have made toward fulfilling their determination, voiced at that conference, to achieve a common standard. "We prepared a design," said Mr. Harley, "which we felt was the most effective solution, bearing in mind practical and economic considerations" and this has been submitted to the members of 39 research and engineering bodies and 59 trade associations for comment. Complete replies are not yet received, but the early returns, which appear to be typical of the whole group, disclosed this reception of the proposed standard:

19½% indicated opposition.
17% gave no opinion, and
63% expressed support.

Design Papers Highlight A.S.M.E. Sessions

LIVELY DISCUSSION featured the two Machine Design sessions, drawing record attendance during the A.S.M.E. annual meeting at the Hotel Pennsylvania in New York. Held on December 6, 1946, five papers were presented, dealing with design problems ranging from strength of machine parts to cam kinematics.

In his paper "Stress and Strength Requirements in the Design of Machine Parts", Dr. Charles Lipson, Detroit consulting engineer, emphasized that balance between stress and strength is the basic concept governing all structural problems. Dr. Lipson stated that working stress can be static, resulting from conditions such as driving torque of an engine, preload of the suspension spring or residual stress produced in a shaft by straightening, on dynamic, resulting from torsional fluctuations of a crankshaft, flutter of a fan or reaction of the suspension members to road irregularities.

Strength is the maximum stress that the material in its fabricated form can sustain when subjected to working stress, and includes hardness of the material, size of the member, surface conditions and type of service loading. Dr. Lipson cited how proper proportioning of an existing gun ejector to properly distribute the stress decreased the weight and increased the life four fold. (See PRODUCT ENGINEERING, Dec. 1946, page 131). Another example showed that straightening axle shafts created internal stresses that reduced the average service life 30 percent.

During discussion, Dr. J. O. Almen of General Motors Corporation explained that straightening is sometimes used to induce compressive stress to increase the life of a part such as leaf springs. By precise analysis, connecting rods and other parts have been improved on the basis of stress-strength charts. (See PRODUCT ENGINEERING, March 1946, page 205 and Sept. 1946, page 130). In automotive design minimum values are used, rather than a statistical average.

Replying to questions on his paper "Design Features of Large Horizontal Surface Broaching Machines", George R. Squibb of Cincinnati Milling Machine Co. explained that "efficiency" in the ordinary sense was not significant in these machines. For example, instead of the average removal of 1½ cu. in. of material per hp. per min. for ordinary machine tools, large broachers do only about ½ cu. in. per hp. per minute. However, because about 90 percent of the machining cost is operator and perishable tool cost, and only 10 percent for both power and overhead, horsepower efficiency of cutting is a negligible consideration.

Mr. Squibb explained that five vane-type 30 hp. pumps are used instead of a single 150 hp. variable delivery pump for reliability, because failure of one pump does not stop the machine but merely reduces production rate 20 percent; simplification of maintenance and quicker repair; and reduction of spare motor expense. No larger hydraulic system is needed because the machine now completes about 1 block per min., which is as fast as an operator can work.

Wide applications of electric strain gages were discussed by P. E. Nokes and E. G. Carr of United Shoe Machinery Corp. in their paper "The Use of Electric Gauging Equipment in Machine Design." Using the electrical strain gage the authors determined: (1) Loading between flat surfaces up to several thousand pounds, (2) measurement of hydraulic and pneumatic pressures, (3) data for calculating rotational velocity and acceleration. Eventually the company expects to use these devices to explore dynamic load on cam surfaces.

New President of the American Society of Mechanical Engineers — Eugene W. O'Brien, consulting engineer and vice president of the W.R.C. Smith Publishing Company of Atlanta, Georgia, succeeding D. Robert Yarnall, president of the Yarnall-Waring Company of Philadelphia. Mr. O'Brien took office at the close of the A.S.M.E. annual meeting on December 6, 1946.

Two outstanding papers were presented at the afternoon session of the Machine Design Group. Allan H. Candee of the Gleason Works demonstrated how the general principles of geometry and kinematics can be applied to cam design. He explained many of the properties of the involute curve that are not dealt with in the usual textbooks. Mr. De Jonge of the Babcock and Wilcox Company presented a written discussion on some of the points brought out by Mr. Candee.

The second afternoon paper, "A Theoretical Derivation of Ball Bearing Rating" by Thomas Barish, consulting engineer, created considerable discussion and comment primarily because of its possible effect on the standardization of ball bearings ratings.

Design engineers also expressed interest in papers presented at sessions of the Production Engineering Division, the Metals Cutting and the Metals Engineering Division. An outstanding paper titled "Shot Peening" was presented by J. O. Almen, Research Laboratories, General Motors Corp., Detroit, Michigan. Mr. Almen demonstrated that the strength of structural materials can be greatly increased by development of residual stress of proper orientation and magnitude within the part. Beneficial or harmful residual stresses resulting from normal heat treatment and mechanical operation must be understood so they can be applied in the normal processing of machine parts. Some of this information is discussed in the August, 1946 issue of PRODUCT ENGINEERING, beginning on page 81.

A paper titled "Machinability, Tool Life and Machine Tools" by George C. Schlesinger, Consultant, Loughborough, Leicester, England, urged that the American Standards Association define machinability. Dr. Schlesinger's ideas about machinability differ somewhat from those expressed by engineers of this country. This paper was not preprinted, but some of the matter discussed in it was published in *American Machinist*, November 21, 1946.

Another subject discussed, of interest to designers, is surface finish. A paper titled "Surface Roughness, Waviness, and Lay and Its Application in Actual Practice" by Walter Mikelson, covered the use of specimen surfaces in shop production methods at the General Electric Company. It connected the use of these surface blocks with specification on drawings for desired surface

in production. Mr. Mikelson also discussed comparing these surfaces, and their establishment in accordance with the system of preferred numbers. "The Proficorder—An Instrument for Recording Surface Waviness and Profile" was the title of a discussion by Dr. Ernest J. Abbott on an instrument for measuring and gaging surface records. Another paper, "Tracer Point Sharpness as Affecting Roughness Measurements", by D. E. Williamson also dealt with surface roughness.

ASME Meeting Has International Theme

PARTICIPATION OF AMERICAN ENGINEERS in a permanent World Engineering Conference, with headquarters in Paris, was decided at the annual meeting of the American Society of Mechanical Engineers held in New York. The new world technical body will have a practical working contact with the United Nations Educational, Scientific and Cultural Organization.

The Committee on International Relations of the Engineers Joint Council is the medium for organizing American participation. Its chairman is Malcolm Pirnie and its secretary is Stewart E. Reimel, with headquarters in the Engineering Societies Building, 29 West 39th Street, New York. It plans to set up a national committee, with all United States engineering societies invited to be represented, as soon as formal sanction is received from the Engineers Joint Council.

Plans for the World Engineering Conference were formulated during the International Technical Conference held in Paris (see November "Foreign Reports"). At that time contact was established with UNESCO through the director of its engineering section, Dr. Yeh Chu-Pei, American-educated Chinese. He emphasized to the American engineers the need for a single world organization through which it would work in bringing to the profession its support and benefits.

American engineers have a duty, the logical result of their accomplishments, to assume a position of leadership, according to Clarence E. Davies, secretary of A.S.M.E. Likewise they have a vital interest in making their influence felt and in gaining through contact with engineers in other countries. Highlights of the meeting included:

A panel on. "A Basic National Labor Policy," with two speakers from management and two from labor, and a management session on "Real Wages and Higher Production," with talks by Leon Henderson, former O.P.A. administrator, Michael Ross, chairman of international affairs for the C.I.O., and Rufus Tucker, General Motors Corp. economist.

An address was given by Paul G. Hoffman of South Bend, Ind., president of the Studebaker Corp., on "The Outlook for Freedom."

Joint sessions with the American Rocket Society, an affiliated organization, were held dealing with rockets, jet propulsion, Naval pilotless aircraft, supersonic and transonic aircraft problems.

APPOINTMENT OF DR. WALTER RAMBERG as Chief of the Engineering Mechanics Section of the National Bureau of Standards has been announced by Dr. E. U. Condon, Director of the Bureau. Dr. Ramberg, who has directed the Bureau's aeronautical research program since 1937, succeeds Mr. H. L. Whittemore, recently retired.

Dr. Ramberg is noted for his work in aeronautical research, especially in the field of aircraft structures. He has contributed extensively to scientific literature on the strength of materials, the strength and instability of structural elements of aircraft, and the vibration of propellers. The most recent of a number of vibration measuring instruments developed by Dr. Ramberg is an electronic tube known as a vacuum tube acceleration pickup, designed to record rapidly changing accelerations of portions of an airplane in flight and now proving useful to the Army and Navy in studies of accelerations imposed on pilots in crash landings.

RECENTLY ELECTED SOCIETY OFFICERS

National Lubricating Grease Institute, 498 Winfield Ave., Buffalo, N. Y. President—H. P. Hobart, Gulf Oil Corp.; Vice President—J. R. Corbett; Treasurer—E. V. Moncrieff; Recording Secretary—George W. Miller; Executive Secretary—Carl E. Bolte.

Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y. President—Gilbert K. Hardacre, Public Service Company of Northern Illinois; Vice President—Lee E. Tayler; Secretary—Walter Sturrock; Treasurer—Charles H. Goddard.

Engineering Societies Council of New York, 29 W. 39 St., New York 18, N. Y. Chairman—H. C. R. Carlson, American Society of Mechanical Engineers; Vice Chairman—H. P. Wall, American Society of Safety Engineers; Secretary—M. P. Davis, A.S.T.M.; and Treasurer—H. F. Dart, I.R.E.

MEETINGS

January 14-17
Material Handling Exposition—Public Auditorium, Cleveland, Ohio.

January 19-24
Canning Machinery and Supplies Association Exhibit—Atlantic City, N. J.

January 23-26
Society of the Plastics Industry—Low Pressure Division, Edgewater Beach Hotel, Chicago, Ill.

January 27-31
American Institute of Electrical Engineers—Winter meeting and Electrical Engineering Exposition, New York, N. Y.

January 27-31
International Heating and Ventilating Exposition—Lakeside Hall, Cleveland; concurrent with meeting of **American Society of Heating and Ventilating Engineers.**

January 28-February 2
Society of Plastics Engineers—Annual meeting and exhibition, Congress Hotel and Navy Pier, Chicago, Ill.

February 3-6
Automotive Accessories Manufacturers Association—Atlantic City, N. J.

February 17-20
Concrete Industries Exposition—Hotel Sherman, Chicago, Ill.

Plastic Bonds Resistant To Temperature Changes

SATISFACTORY BONDING between a plastic and a metal facing or metal reinforcement has been practically impossible in the past, primarily because the two types of materials differ in their coefficients of expansion. Plastics have relatively high coefficients of expansion, in contrast to metals, and changes in temperature create forces that prevent satisfactory bonds. Investigations at the National Bureau of Standards by P. S. Turner of the Plastics Section have shown that the coefficients of thermal expansion of components can be matched, giving a bond resistant to temperature changes.

Bonds produced by adhesives fall into two classes: The rubbery or yielding bond and the rigid bond. The first category includes most thermoplastic cements, rubber cements, and combinations of thin rubber layers and cements. These adhesives provide durable bonds between dissimilar materials at moderate temperatures. The rigid bond has generally proved unsatisfactory for such applications with the possible exception of cold-setting cements of phenol-formaldehyde and urea-formaldehyde types. At reduced temperatures, however, the yielding adhesives lose their ability to eliminate stress concentrations by yielding with the dimensional changes of the materials bonded. If it can be obtained, the rigid bond is superior for many purposes because it produces a stronger and less-yielding product. For composite structural material subjected to extreme temperature changes, a stable rigid bond is imperative. The solution lies in the matching of thermal-expansion coefficients of the components.

A formula developed by P. S. Turner gives the resulting volume thermal coefficient of a mixture. The formula has been used successfully in a number of applications. A mixture of polystyrene and aluminum oxide, for example, was determined in this fashion so that brass inserts were feasible. Brass inserts in ordinary polystyrene cause the polystyrene to crack as a result of the differences in thermal-expansion coefficients. The coefficient of linear expansion of polystyrene is approximately 70×10^{-6} per degree Centigrade while that of brass is about 17×10^{-6}. Fused aluminum oxide was chosen for use in the mixture because it has a low coefficient of linear thermal expansion—8.7×10^{-6}—and a high modulus of elasticity compared to its density. Its choice for use with polystyrene was also determined by its desirable electrical properties, and there was no appreciable change in the electrical resistance of polystyrene on addition of the filler.

Calculations revealed that approximately 90 percent of polystyrene and 10 percent of aluminum oxide would be required to match the coefficient of linear thermal expansion of brass. Analysis with polarized light indicates that there are stresses in the pure polystyrene concentrated at the boundaries between the brass and polystyrene, and these are sufficient to rupture the polystyrene. With about 10 percent of fused aluminum oxide filler, such stress concentrations are absent and there is no evidence that the filled styrene has fractured. The brass was sufficiently well bonded to the polystyrene to permit sawing and machining of the composite.

Rivet fillers for aluminum, used to cover the depressions caused by riveting, have been developed by this method, as well as glass-plastic laminates to match aluminum reinforcing plates.

Phase and "Polanret" Microscopes

THE PHASE MICROSCOPE, hardly out of the development stage, has already been refined. Announced by physicists of the Research Division of the American Optical Company, Buffalo, N. Y., the "polanret" microscope is said to be a more flexible instrument for accomplishing the results attained with the present phase microscope.

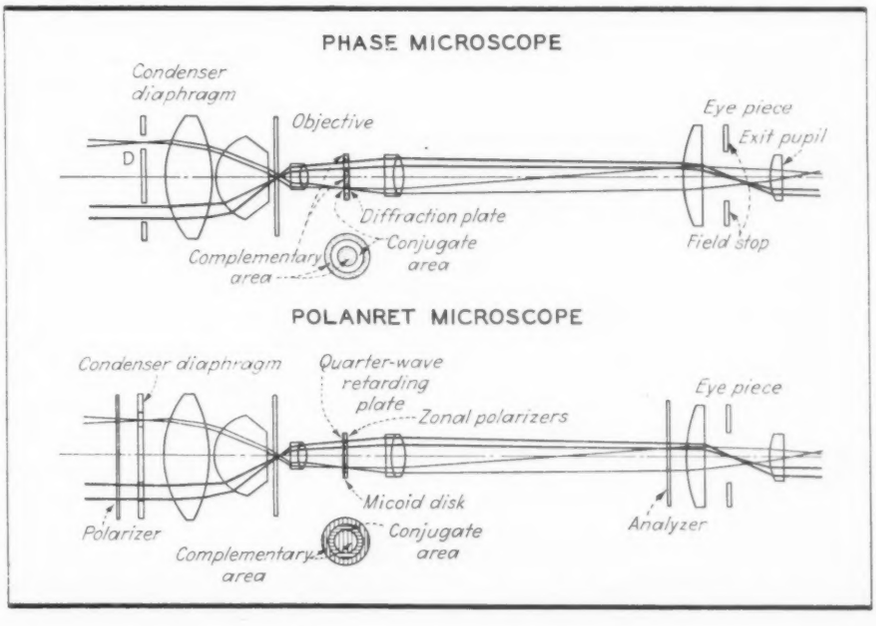
The phase microscope (shown in the accompanying diagram) differs from the usual microscope only in the introduction of a condenser diaphram *D* and of a diffraction plate at the objective.

The phase microscope promises to be of great importance. In nature and industry there are many microscopic materials that are transparent or nearly so, the details of which differ from their background in either refractive index or actual thickness. The phase microscope makes such details visible without the use of stains, dark-fields, or other special preparations.

The direct method of introducing diffraction plates used in phase microscopy would be fully satisfactory were it not that to obtain the desired contrast in the image of several objects, and sometimes even for a single specimen, a series of well chosen diffraction plates is often required, entailing both cost and inconvenience.

The polanret microscope is one solution to this problem. The trick consists of polarizing the conjugate and complementary areas, preferably at right angles. This is accomplished by replacing the diffraction plate by two zonal polarizers of high optical quality. One of these covers the conjugate area; the other, the complementary area.

Polanret microscopy is somewhat more complex than phase microscopy, and requires a great deal of development to perfect it for the high-powered microscope objective. With standard 10x objectives of focal length 16 mm. and longer, the new method will give excellent results.



DIMENSIONS AND TOLERANCES
Fundamental Principles

MERHYLE F. SPOTTS
Associate Professor, Northwestern University

First of a series of two articles. Discusses the necessity and fundamentals of specifying tolerances. The relative advantages of unilateral and bilateral and of cumulative and non-cumulative tolerancing methods are outlined. Selective assembly for parts requiring small tolerances and the use of datum surfaces is explained.

TOLERANCES must be placed on the dimensions of a drawing in order to limit the permissible variations in size because it is impossible to machine a part exactly to a given dimension. While small tolerances give higher quality work and a better operating mechanism, the cost of manufacture increases rapidly as the tolerances are reduced. Fig. 1 shows a typical relationship between tolerances and cost. It demonstrates the importance of specifying tolerances at the greatest values that the operating or functional considerations will permit.

The development of production processes for large volume manufacture at low cost has been largely dependent upon interchangeability of component parts. Thus the designer must determine both the proper tolerances for the individual parts and the allowable clearance or interference to for assembly with connecting parts.

The manner of placing tolerances on drawings depends somewhat on the personal preference of the design engineer. In some cases, if the tolerance on a dimension is not specifically stated, the drawing contains a blanket note giving the value of the tolerance for such dimensions. However, some designers do not use blanket notes on the supposition that if each dimension is considered individually, wider tolerances than those called for in the note would probably be specified. In any event it is highly important that a drawing be free from ambiguities, and be subject to one and only one interpretation.

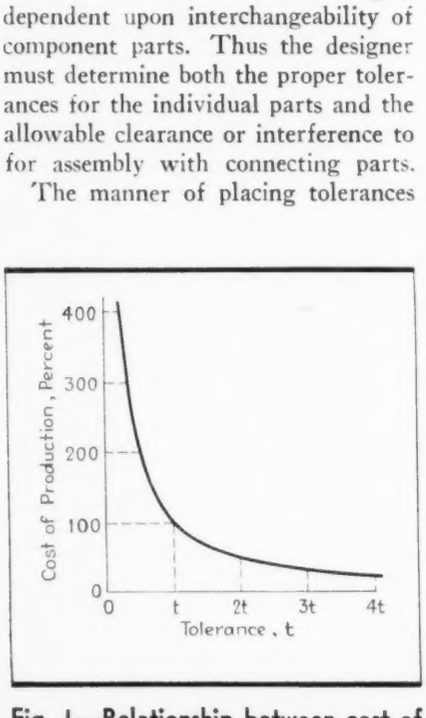


Fig. 1—Relationship between cost of production and tolerances.

Unilateral and Bilateral Tolerances

The tolerances for a cylindrical fit, for example, may be placed on a drawing in a number of different ways. Fig. 2(*A*) shows the unilateral method in which one tolerance dimension is zero, and the other tolerance takes care of all the permissible variation in size. The basic dimensions (4.000 and 3.997 in.) are those dimensions that would be used if it were possible to manufacture the part without error. It is customary in clearance fits to specify the maximum metal condition by the basic dimensions. By so doing the clearance for the most difficult assembly condition can be obtained directly from the basic dimensions without the need of paying attention to the tolerances. The directions of the tolerances are then such as to recede from the most difficult condition.

The conditions shown in Fig. 2(*A*) represent what would nominally be called a "4 inch shaft." It should be noted however that the 4 in. dimension is placed, not on the shaft, but on the dimension for the hole. When this is done the dimensioning is said to be on the Basic Hole System. This method is advantageous because the manufacturing departments can use standard size reamers for the holes, and then machine the shafts to fit.

On the other hand the manufacturing departments may prefer to use ground shafting of standard sizes. When this material is used the holes must be made to fit the shafts. The nominal shaft size should then appear in the dimensions for the shaft and not for the hole. This method of dimensioning is known as the Basic Shaft System. Fig. 3(*A*) shows the case of Fig. 2(*A*) when dimensioned in the basic shaft system.

The upper and lower limits are sometimes given in full as shown in Fig. 2(*B*). When this method is used there is no need of making arithmetical calculations for finding the limiting sizes, and the possibility of making mistakes is reduced. A definite procedure is used for the order of stating the dimensions. In Fig. 2(*B*) the top figures give the maximum metal condition, and the shop workman would aim to machine to these upper dimensions. If he misses, but lands in the tolerance zones, the parts will still be acceptable.

Bilateral tolerances, when used for the same example, are illustrated in Fig. 2(*C*). Figs. 3(*B*) and (*C*) show examples of interference fits when dimensioned in the basic hole and basic shaft systems, for minimum metal.

The unilateral system of dimen-

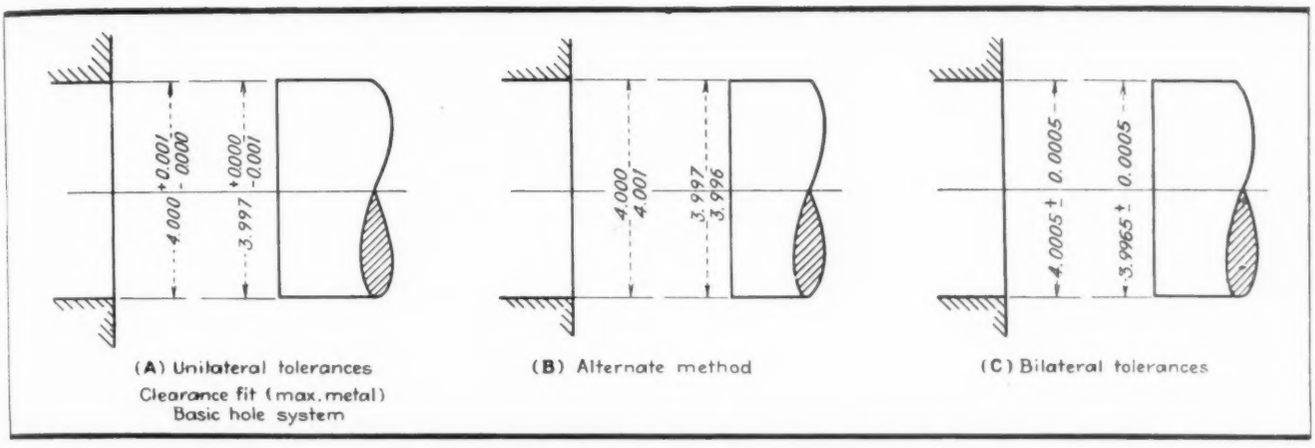


Fig. 2—Methods of indicating tolerances.

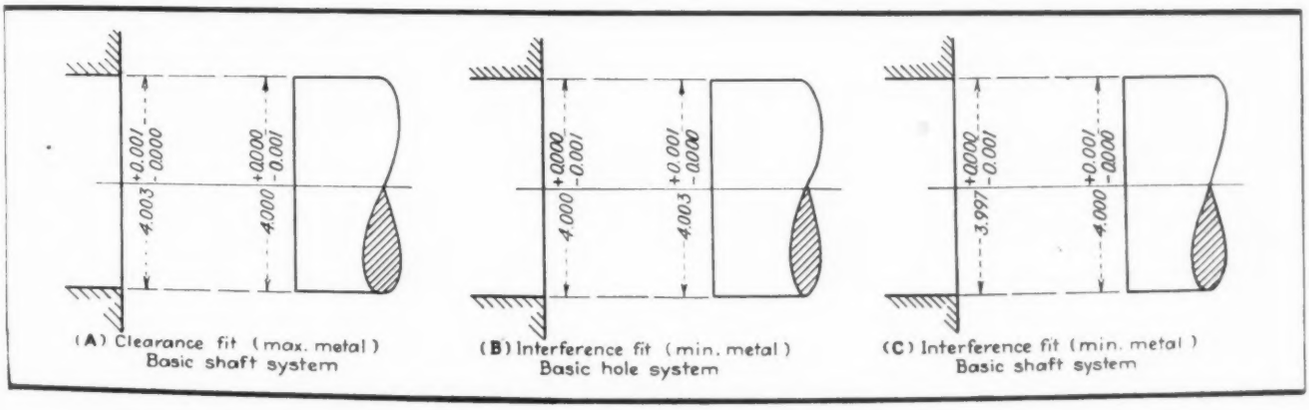


Fig. 3—Dimensions of various types of fits.

sioning possesses distinct advantages in interchangeable manufacture. In Fig. 4, the original tolerances for hole and shaft are represented to scale by h_1 and s_1 respectively. It may be found feasible to increase the tolerances on the parts to h_2 and s_2 and thus effect additional economies of manufacture. Should the new and old parts be mixed together, Fig. 4 indicates that no difficulty will be encountered in the assembly of a part made when the hole tolerance was h_1 with a shaft made to a tolerance of s_2. Also parts made with s_1 and h_2 tolerances will assemble freely.

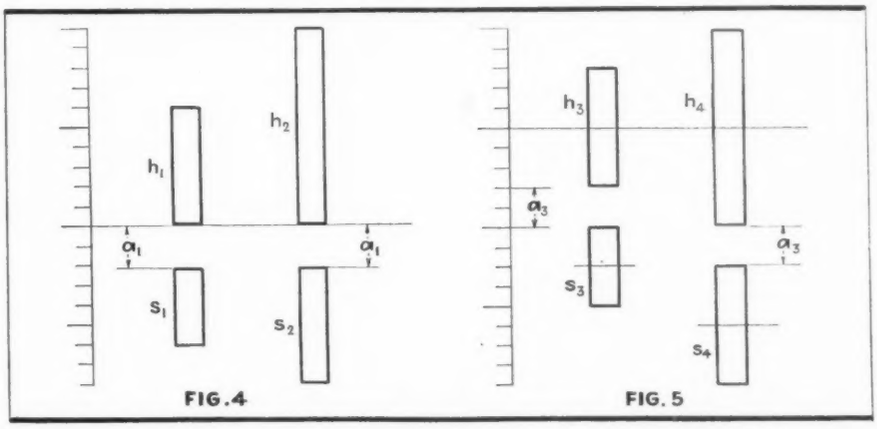


Fig. 4—Diagram showing unilateral tolerances. Fig 5—Bilateral tolerances.

The situation may be quite different had the original dimensioning been done on the bilateral system. In Fig. 5 the original tolerances are represented by h_3 and s_3, and the revised tolerances by h_4 and s_4. While parts made with h_3 and s_4 tolerances will assemble, a clearance fit between parts with s_3 and h_4 tolerances may not be possible. Thus if the unilateral system of tolerances is used, the value of the tolerances may be changed at will without incurring difficulties in the assembly of a mixture of new and old parts. Drawings containing unilateral tolerances are also easier to check than those containing bilateral tolerances.

There are places where the bilateral method of tolerancing is very appropriate. The location of hole centers, for example, in which the variation from the basic dimension is equally dangerous in either direction, are usually so dimensioned. For practical manufacturing purposes, welded assemblies may be dimensioned with bilateral tolerances. The same applies to loosely toleranced dimensions. When the tolerances are large it is sometimes more convenient to give the mean dimension, and the variation each way as plus or minus values.

Fits between mating parts are designed by the terms "class" and "grade." The class of the fit refers to the allowance *"a"*. The grade refers

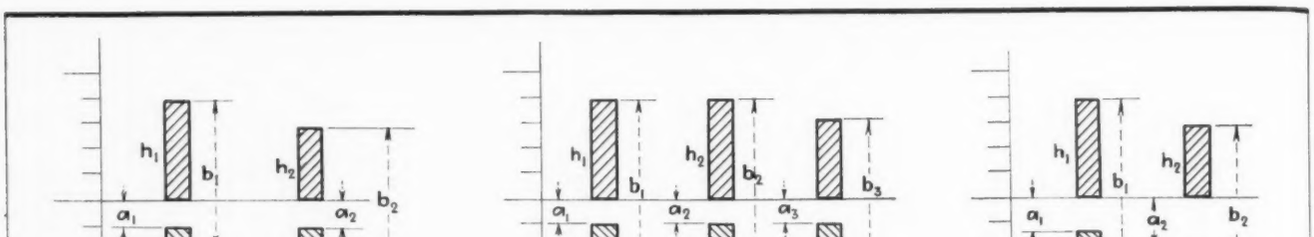

Fits of same class, $a_1 = a_2$
" " " grade, $b_1 = b_2$
Fits of same class, $a_1 = a_2 = a_3$
" " different grades $b_1 \neq b_2 \neq b_3$
Fit of different classes, $a_1 \neq a_2$
" " " grades $b_1 \neq b_2$

Fig. 6—Bar diagram of tolerances for different classes and grades of fits.

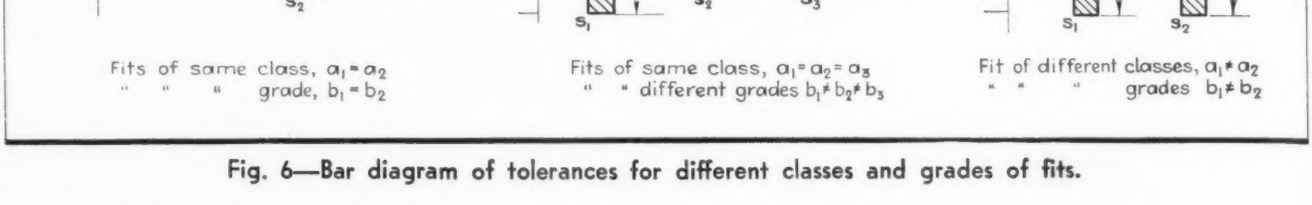


Fig. 7—Dimensioning for selective assembly.

to the maximum clearance *"b"* for an assembly at the loosest condition. Fig. 6 illustrates, by bar diagrams, the various possibilities of classes and grades for shafts and holes.

Selective Assembly

There is no difficulty in maintaining suitable tolerances if the fit is very loose. The same is true for very tight fits or fits having considerable interference. However when the difference between allowance and maximum clearance must be small, the tolerances for hole and shaft may become excessively small with a consequent increase in the cost of production.

These costs may be minimized by selective assembly, which consists of first making each of the mating parts with large tolerances and then sorting them into groups having small tolerances. For example in Fig. 7(*A*), it is necessary that the clearance between a hole and shaft should vary from 0.0004 to 0.0010 in. The tolerances for each part, if divided equally, will thus be only 0.0003 in. and the cost of manufacture would be high. If selective assembly is used the tolerances can be increased to larger values as shown in Fig. 7(*B*). The bar diagram for this fit, given in Fig. 7(*C*), indicates that the parts are to be sorted into three groups, each with a variation in size of 0.0003 in. as shown in Table I. If the group of parts with the h_1 holes is now assembled with the s_1 shafts the resulting fit will vary only by the desired amount of 0.0004 to 0.0010 in. The h_2 holes are assembled with the s_2 shafts and so on. Selective assembly is thus a systematic process and not mere trial and error.

Selective assembly will give a closely controlled fit even with relatively

Table I—Dimensions of Holes and Shafts for Selective Assembly Operations

Group	Holes		Shafts		
	Basic Size, in Inches	Tolerance, in Inches	Group	Basic Size, in Inches	Tolerance, in Inches
h_1,	2,5006	0.0003 −0000	s_1,	2,5002	0000 −0.0003
h_2,	2,5003	0.0003 −0000	s_2,	2,4999	0.0000 −0.0003
h_3,	2,5000	0.0003 −0000	s_3,	2,4996	0.0000 −0.0003

large shop tolerances. The method however has a number of disadvantages. The sorting operation and the requirements for additional gages increase production costs. Universal interchangeability is no longer maintained. Servicing is more complicated, and may require that a whole subassembly be replaced rather than a single part. After sorting, unless the parts are made in large quantities, the corresponding groups of components, which must be assembled together, may not contain equal numbers of parts. Selective assembly however is advantageous for interference fits where small changes in size may either cause the fit to become too loose to hold, or so tight that the pressfit stresses are excessive.

Cumulative and Non-Cumulative Tolerances

Unnecessarily small tolerances sometimes result from the use of cumulative or compound tolerances. For example, the functional requirements of a part may be such as to permit a tolerance of 0.005 in. from the datum plane for each of the vertical surfaces shown in Fig. 8(*A*). When each surface is dimensioned individually from the datum plane, full advantage is taken of the permissible variation in size. If the dimensioning is done chain fashion from surface to surface as shown in Fig. 8(*B*), the variation of 0.005 in. in the overall length must be divided among the five dimensions and the permissible tolerance between any two neighboring surfaces is reduced to 0.001 in., with consequent increase in manufacturing difficulties. Thus cumulative or compound tolerances should, in general, be avoided.

On the other hand, suppose the relationship between certain features must be held within small limits but that a relatively large variation in their location from the datum plane is permissible. In such cases the introduction of a compound tolerance by the use of a secondary datum plane may be preferable to non-cumulative dimensioning. Suppose in Fig. 9 that the maximum permissible variation in spacing between the groups of holes is 0.004 in. but that the location of the groups from the datum plane may vary by a total of 0.010 in. When non-cumulative tolerances as in Fig. 9(*A*) are used, no use can be made of the large permissible tolerance to the datum plane. If a secondary datum plane passing through Group B is chosen, and the dimensioning done as in Fig. 9(*B*), a compound tolerance is introduced, but use can be made of the large tolerance on the dimension between the primary and secondary data.

Datum and Functional Surfaces

The surfaces of a part perform various duties in fulfilling the objective of the design. The surfaces to which the various features of a part are located, by means of dimensions, are called the datum planes. The functional surfaces are those operating or positioning surfaces that control the operation or location of the mechanism. Clearance surfaces provide continuity in the part, but have no functioning characteristics. Atmospheric surfaces such as the outside of castings and exposed bolt heads have no contact relationship to the other surfaces of the part.

The datum surfaces of a part will in general consist of three mutually perpendicular planes. In order to

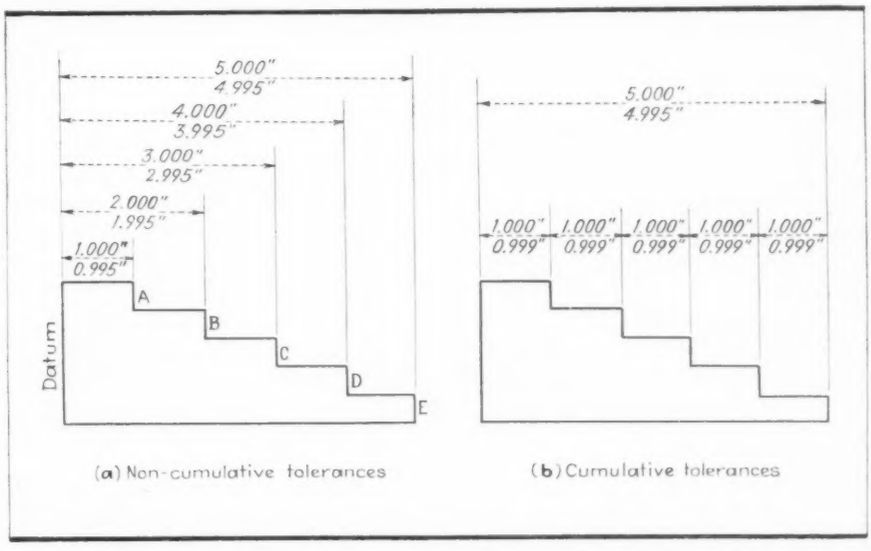


Fig. 8—Dimensioning with cumulative and non-cumulative tolerances.

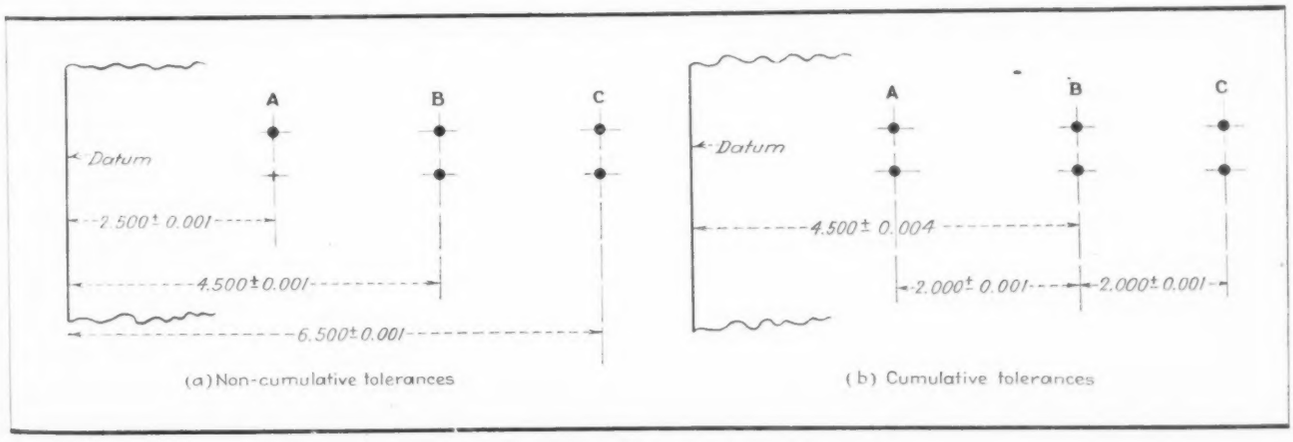


Fig. 9—Dimensioning with secondary datum planes.

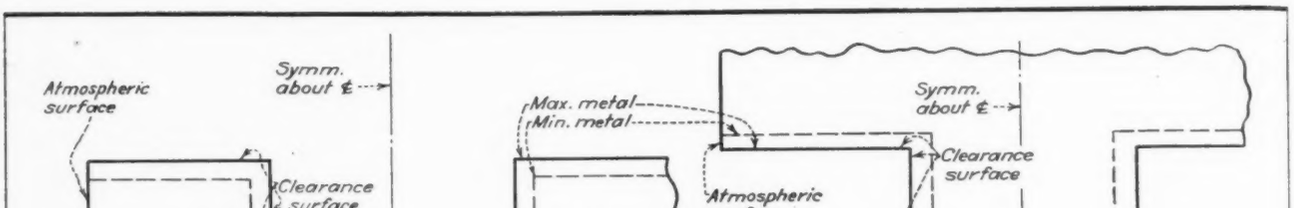


Fig. 10—Tolerance zones for T-slide.

facilitate manufacture and inspection, it is important that the datum surfaces pass through actual physical features on the part and not be merely imaginary planes in space. The plane through the centerline of a symmetrical part is very convenient from an engineering viewpoint as a datum for giving the dimensions. The measurement of such a part, when the centerline is devoid of all physical features, may be difficult because of the variations in the tolerances.

The operation of a T-slide, for example, necessitates the tolerance zones being arranged symmetrically about the centerline as shown in Fig. 10. It would be very desirable from the manufacturing and inspection standpoints to use one of the functional surfaces as the datum for horizontal dimensions instead of the imaginary plane through the center. In general however, it will be found that once a datum is chosen, and the tolerance zones established in relationship to it, that it will not be possible to shift the dimensioning to a new datum and preserve the same tolerance zones originally laid down. If it is possible to place two holes on each of the central datum planes, dowels may be fitted therein that will permit these planes to be located with respect to the tools for machining, as well as the surface plate for inspection.

It is good practice to mark the datum planes on the drawings, and thus make certain that no misunderstanding can arise by the shop workmen choosing an incorrect plane. Sometimes a special symbol is used on drawings for marking these planes. The datum planes should conform as nearly as possible with the locating points for the machine tools or fixtures, as well as the inspection gages.

[EDITOR'S NOTE: A sequel to this article "Recommended Practices for Dimensioning and Tolerancing" written by Professor Spotts will appear in the February 1947 issue of PRODUCT ENGINEERING.]

Case Histories In Patent Law

H. A. TOULMIN, JR.

(EDITOR'S NOTE: These explanations of the law in specific patent cases are not intended to supplant the services of a patent attorney, whose accurate advice is necessary to handle individual patent problems. The purpose of these explanations is to give a better general understanding of patent law.)

NO. 7

QUESTION: When does the control of a patentee over the article manufactured under his patent cease?

ANSWER: This is a vital question, particularly in connection with controlling the first price at which the patentee's article is sold either by himself or by his licensee. The Supreme Court of the United States had occasion to consider this problem in connection with the sale of eyeglass lenses. In that case, due to the practical conditions of the trade, the owner of the patent could only manufacture the lens blanks in the finished or semi-finished condition and then supply them to its licensees who were opticians or optometrists in direct contact with the patients. After prescribing for the patient, the lenses had to be ground from the blanks furnished by the patentee—manufacturer in order to enable each pair of lenses to fit the eyes of the particular patient.

Obviously, this could not be anticipated in advance. Therefore the patentee could only carry his manufacturing so far as the blank and must leave to the distributing channels the grinding of the lenses to particular specifications of patients. Accordingly, the patentee licensed the distributing channels such as the optometrists, opticians and those who would grind the lens blanks into lenses in order to complete the article within terms of the patent.

To insure quality, the patentee also required that its licensees should sell the completed lenses at stipulated prices. This condition went on for many years and millions of dollars of lenses were sold until the United States government complained that this was illegal price fixing.

The Supreme Court of the United States held that if the lenses were sold outright in blank form by the patentee that the monopoly of the patentee then ceased and he would be unable to control either the quality of the manufacture of the completed lenses by his licensees or the price at which his licensees sold the completed lenses. And this despite the great public interest in the matter in that the control of the licensees protected the patient from defective lenses. United States v. Univis Lens Co. Inc. et al, 316 U. S. 241.

NEW BOOKS

Machining Aluminum Alloys

Prepared and published by Reynolds Metals Co., Department 47, 2500 So. Third St., Louisville 1, Ky. 6 x 9 in., paper covers. 124 pages. Price $1.

The first section of the book contains eight 2-page tables, each of which applies to a particular machining operation. Recommended tool angles and contours, speeds, feeds and depths of cuts for different types of tools are given. The remainder of book discusses the details of the machining operations to which the tables apply. The factors on which the recommendations in the tables were based are explained. Cooling and lubrication is discussed and helpful suggestions are made.

Machine Design

V. L. MALEEV. *First Edition (Revised), Fifth Impression. 581 pages, blue clothboard covers. Published by the International Textbook Co., Scranton, Pa. Price $5.*

The revision of the First Edition of this standard textbook has been modernized. Ten pages, treating screws with ball nuts, have been added to Chapter 13, Screws for Power Transmission. A page of problems on screws with ball nuts is included in an appendix.

Induction Heating

OSBORN-BRACE-JOHNSON-CABLE-EGAN. *172 Pages, 6x9 in., red cloth binding. Published by the American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio. Price $3.*

This book is based on a series of five educational lectures given by the authors at the National Metals Congress in February, 1946. Mr. Osborn's section on principles of induction heating covers the basic theories involved, the available types of high frequency supplies, the effects of different frequencies on the depth of heat penetration and the power requirements to produce heat penetrations of different depths. The section on induction circuits and generators, prepared by P. H. Brace, gives the fundamentals and characteristics of the various types of electrical circuits suitable for high frequency work. Practical applications of induction heating are discussed by W. G. Johnson. The materials, hardnesses and depths of penetration suitable for various types of parts are given. The type of stresses present in induction hardened parts are discussed. Brazing, welding and melting by induction heat are outlined by J. W. Cable in a discussion of practical applications of induction heating with frequencies over 100,000 cycles. Some practical applications of dielectric heating are also given. In a comparison of induction heating with other methods of heating, T. D. Eagan outlines the advantages and disadvantages of induction heating.

Trane Air Conditioning Manual

REUBEN TRANE. *Seventh printing, Aug. 1946. 376 pages, 8½ x 11 in., clothboard covers. Published by The Trane Co., La Crosse, Wis. Price $5.*

The book is concerned primarily with the application of the fundamental facts of engineering to the design of air conditioning systems. It includes heating, refrigeration and ventilation. Many tables and charts, some of which are available as loose sheets, are included not only for convenience in making computations, but also because they clearly show the effect of changing conditions. New developments in the field of air conditioning, which might be regarded by some as controversial matter, have not been ignored.

Practical Designs for Drilling, Milling and Tapping Tools

C. W. HINMAN. *Second Edition. 416 pages, 6 x 9 in., clothboard covers. Published by the McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 18, N. Y. Price $4.50.*

Containing more than 400 illustrations and diagrams this book is a ready reference for designing, drafting and using modern types of drilling, milling and tapping tools. Several examples of right and wrong designs of tools are included, with discussions of the reasons why the wrong designs could not be used. The second edition covers numerous tooling methods that were developed during World War II and subsequent to the publication of the first edition.

For drilling, the discussion includes types of commercial jigs and fixtures; four methods for drilling holes in long sections of structural steel angles; twist drills with stepped cutting points; methods of removing broken drills, taps and reamers; drills for cutting hardened tool steel; Carboloy-tipped gun drills; and 18 examples of grinding drills for cutting various metals. Milling and tapping tools are treated in similar detail.

The preliminary steps in designing and drawing drill jigs and fixtures are covered in the introductory chapter. The last three chapters treat shop mathematics, lubricants and coolants and tool engineering tables.

Human Factors in Air Transport Design

R. A. MCFARLAND. *670 pages, 6¼ x 9¼ in., grey clothboard covers. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York, N. Y. Price $6.*

Discusses the relationship of personal and physiological factors to the design of air transport equipment and the reduction of accidents. The human and operating problems encountered in high altitude flight are outlined. Methods of protection against pressure and temperature changes are illustrated by discussion of the features of different types of airplanes flying over many established routes. Ventilation, temperature and humidity requirements to give safety and comfort are discussed. Methods for designing to permit control of insect and airborne diseases are given. The control of noise and vibration and the effects of acceleration and motion on passengers are discussed. The factors of passenger comfort are thoroughly explored.

The importance of comfort and convenience of the pilot and crew are discussed from the point of view of insuring safety by reducing fatigue and the possibilities of human errors. Throughout the book, examples of actual design and actual failures are used to illustrate the discussions. Much space is devoted to the advantages and disadvantages of various design possibilities.

An Introduction to Electronics

RALPH G. HUDSON. *97 pages, 6 x 8½ in., red clothboard covers. Published by The Macmillan Co., 60 Fifth Ave., New York 11, N. Y. Price $3.*

The science of electronics and many of its applications are explained in terms that can be followed and understood by anyone with an elementary knowledge of mathematics and physics. It gives the reader a general, but scientifically correct, knowledge of the modern theory of the constitution of matter and the behavior of an electric current in a gas, liquid, solid and vacuum. Many major uses of electronic tubes are described and their working principles are illustrated and explained. Chapter topics include flow of electricity, radio communication, sound and picture reproduction, light sources, uses and applications of electronics.

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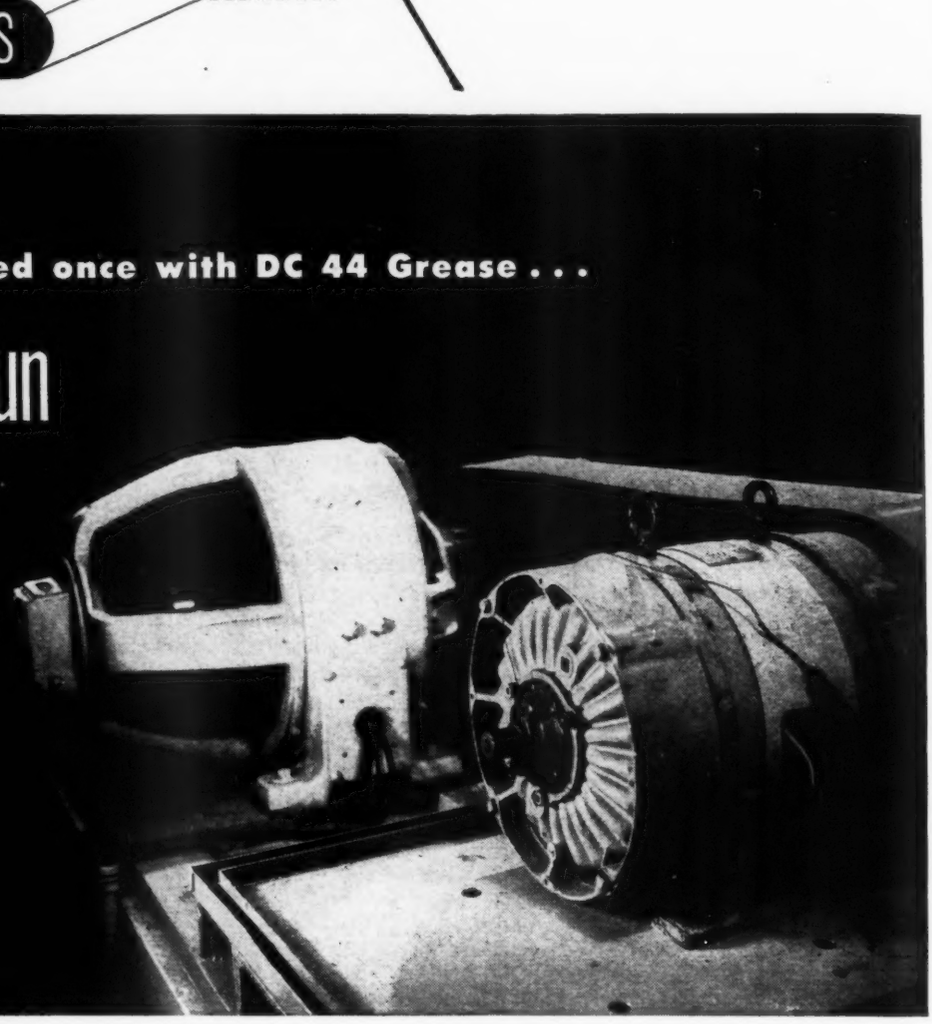

DC 44 Grease is tested in bearings of silicone insulated test motors overloaded to bring bearing temperatures up to 125°C. on the outer race. One application of DC 44 Grease remained serviceable for 3820 hours, 5¼ months, of operation at 125°C.

DC Silicone Greases, like other Dow Corning silicone products, permit operation at temperatures both above and below the limits of comparable organic materials. Developed originally to permit accelerated-life testing of conventionally designed silicone insulated motors, DC 44 is serviceable at temperatures from —40° to 350°F. and at speeds up to 20,000 r.p.m. Very low volatility, freedom from gumming, bleeding of less than 2% after 16 hours at 110°C. (230°F.) and weight loss of only 3.3% after 40 hours at 175°C. (347°F.) are among the conspicuous advantages of DC 44. Other DC Silicone Greases, DC 41 for high temperature low speed applications, and DC 33 for special low temperature (—70°F.) applications, are also covered in data sheet No. C 7-3.

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GEORGE P. SUTTON
Research Engineer, North American Aviation

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$Y_{max.}$ = max. deflection, in.
a = diaphragm radius, in.
w = unit loading pressure, lb. per sq. in.
t = thickness, in.
λ = Poisson's ratio
$m = 1/\lambda$
E = modulus of elasticity in tension, lb. per sq. in.
$S_{max.}$ = max. stress, lb. per sq. in.
S_t = tangential stress, lb. per sq. in.
S_r = radial stress, lb. per sq. in.

The charts are constructed to solve the formulas

$$Y_{max.} = \frac{3\,a^4\,w\,(m^2-1)}{16\,E\,m^2\,t^3}$$

$$S_{max.} = \sqrt{S_t^2 + S_r^2} = \frac{3}{4}\,\frac{wa^2}{t^2}\sqrt{\frac{m^2+1}{m^2}}$$

In Chart A, it is assumed that

$$\sqrt{\frac{m^2+1}{m^2}}$$

equals approximately one. This makes the stress independent of the material, providing the elastic limit of the material is not exceeded. The manner in which the diaphragm is held is important. Unless the diaphragm is held at the edges by hard, finished surfaces, the results obtained will not coincide with those given by the charts. It is recommended that an integral holding flange be used similar to that shown. The following examples are solved on the charts (see heavy dashed lines).

EXAMPLE: What is max. allowable stress of a diaphragm, when

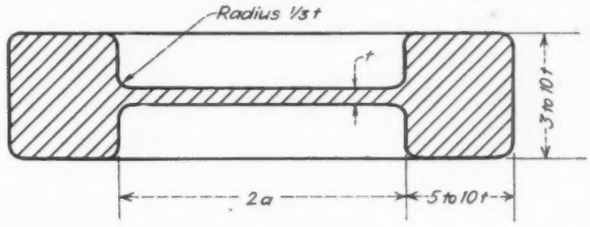
$a = 0.25$ in. $\quad t = 0.03$ in.
$w = 50$ lb. per sq. in.

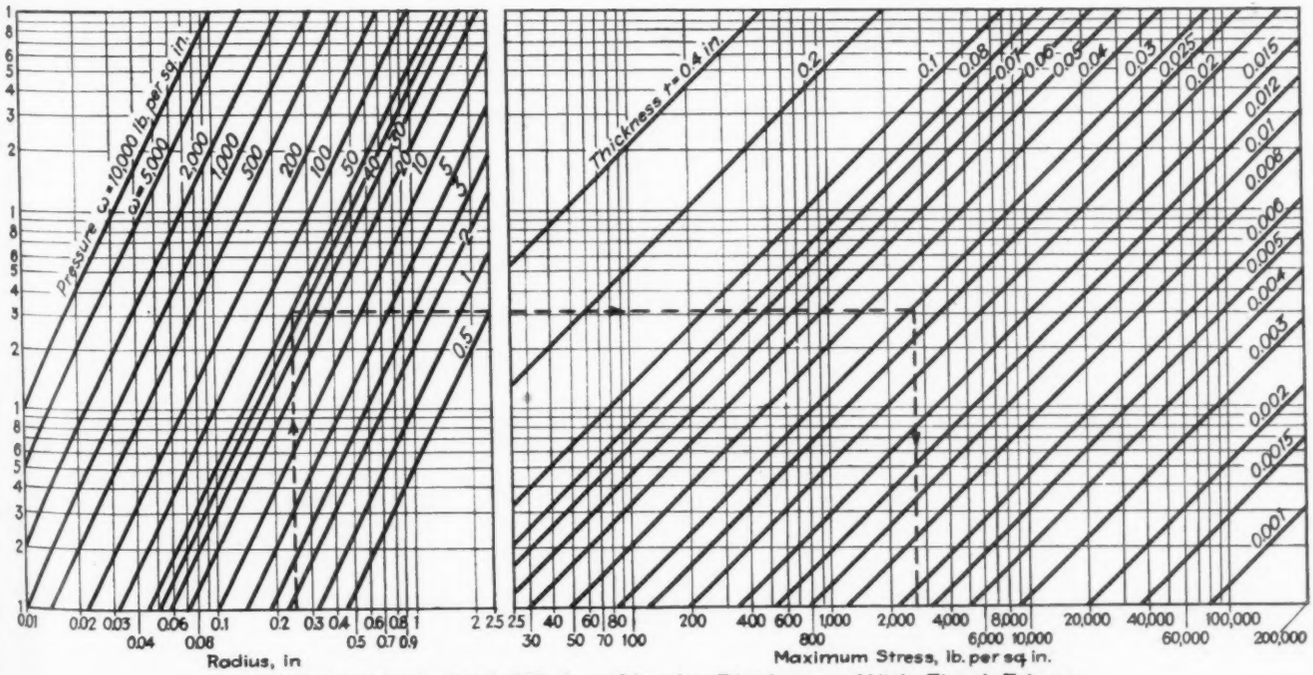
SOLUTION: From point 0.25 on the scale of radii of Chart A, follow ordinate to point of intersection with line w equals 50. Follow abscissa horizontally to point of intersection with line t equals 0.03. Follow ordinate down to scale of maximum allowable stress, and read $S_{max.}$ equals 2,700 lb. per sq. in.

EXAMPLE: What is the maximum allowable deflection of a steel diaphragm, when

$t = 0.0098$ in. $\quad m = 3.85$
$a = 0.20$ in. $\quad E = 30{,}000{,}000$ lb. per sq. in.
$w = 200$ lb. per sq. in.

SOLUTION: From point 0.0098 on the thickness scale of Chart B, follow ordinate to point of intersection with diagonal reference line for steel. Follow horizontally to point of intersection with line a equals 0.2. Follow vertically to point of intersection with line w equals 200. Follow horizontally to scale of maximum allowable deflection, and read $Y_{max.}$ equals 0.0018 in.





DIAPHRAGM CHART A — Circular Diaphragm With Fixed Edges

Specifications alone

DO NOT MAKE A WORM GEAR

Efficient operation and satisfactory trouble-free performance over long periods depend not only upon close adherance to engineering specifications but also upon the selection of materials, highly developed production techniques and high standards of quality control.

The excellence of De Laval worm gears is the result of a combination of all these factors, insuring a quality product that has been proven by the highly satisfactory performance of De Laval worm gears for nearly a quarter of a century.

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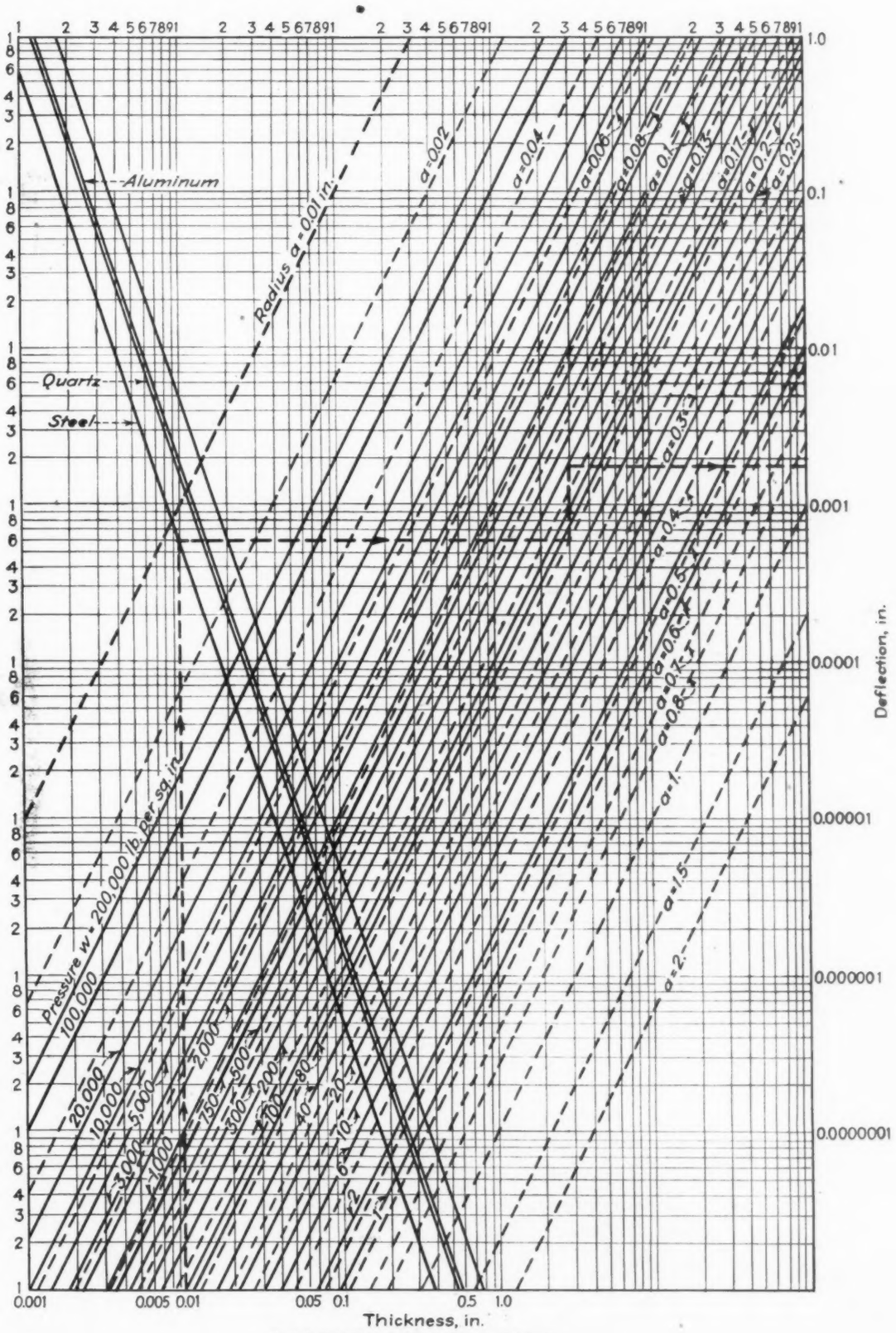
Charts for Circular Diaphragm Design (continued)



DIAPHRAGM CHART B
Circular Diaphragm With Fixed Edges

Aluminum on Steel!

The coating of sheet steel with aluminum for resistance to heat and corrosion was an important milestone in Armco Research. ARMCO Aluminized Steel has a desirable combination of properties. It has the strength of steel, and the atmospheric corrosion resistance and high radiant heat reflectivity of an aluminum coating. And it resists destructive heat scaling up to 1600°F. Aluminized Steel is giving important advantages to many designers—helping them make more attractive, longer-lasting products. Consider this new special-purpose steel when designing *your* products. Write for the informative booklet, "ARMCO Aluminized Steel." The American Rolling Mill Company, 4415 Curtis Street, Middletown, Ohio.

SPECIAL-PURPOSE SHEET STEELS

ALUMINIZED ARMCO STEEL

THE AMERICAN ROLLING MILL COMPANY

NEW MATERIALS AND PARTS

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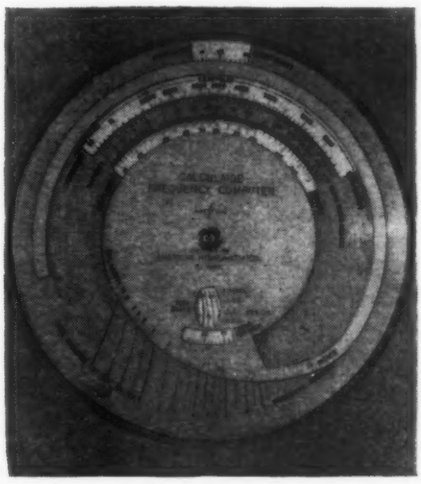
Frequency Computer

American Hydromath Co., 145 West 57th St., New York 19, N. Y.

Problems involving frequency, inductance and capacity are quickly solved with the "Calculaide" frequency computer. This unit correlates, in one setting, the natural frequency and wave length of a circuit comprising a coil and condenser with the physical dimensions of the coil and the capacity of the condenser. All answers are given at a single setting. Inductance values can be determined for varying physical dimensions of coils. The computer's range covers frequencies from 400 kilocycles to 150 megacycles and wave lengths from 2 to 600 meters. It handles condensers of capacity between 3 and 1000 micro-farads. Inductance values which can be determined extend



from 0.1 to 1500 micro-henrys. The device performs calculations with coils of ¼ to 5½ in. diameter, ¼ to 10 in. lengths, 2 to 150 turns per inch, of No. 10 to No. 35 gage wire, whether enameled, single or double silk covered, or single or double cotton covered. The "Calculaide" computer is produced from three sheets of non-warping plastic. All markings are indelibly heat-sealed into the body of the plastic itself.

Volt-Ohmyst

Radio Corporation of America, RCA Victor Division, Camden, N. J.

Utilizing a diode probe and capable of measuring peak-to-peak voltages at very high frequencies, this meter, designated as RCA Type WV-75A incorporates all the refinements of its low frequency companion, the Volt-Ohmyst Type 195A, in addition to circuit inno-

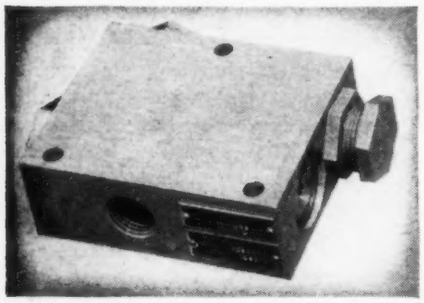
vations that make it useful for high-frequency work. The instrument is six meters in one, comprising a V-H-F voltmeter, audio voltmeter, a.c. voltmeter d.c. voltmeter, ohmmeter, and FM indicator. A full-wave rectifier, built into the a.c. probe, makes possible the reading of both negative and positive voltage peaks at the higher frequencies. The diode probe contains a standard integral female fitting for direct connection to a coaxial line. Measurements at high frequencies are made by direct contact with the central pin and the ground ring at the end of the diode probe, while an alligator clip for

the central pin and the short ground lead serve as adaptors for voltage measurements at the lower frequencies. The RCA WV-75A meter case weighs 9 lb. and measures 9⅝ x 6⅜ x 6¾ in. The steel case of the instrument is finished in gray wrinkle lacquer with an etched brush chrome panel. The meter case is crystal-clear, anti-static coated plastic with a one-piece unbreakable front.

Cut-Out Valve

Electrol, Inc., 85 Grand St., Kingston, N. Y.

The housing of this hydraulic unit is 1¼ in. deep and in plan form measures 2¾ x 3½ in. All four ports pressure, system, return and bleed, are in the same plane. Three of the ports—pressure, return and system are ⅜ in. NPT female ports. The fourth is a ⅛ in.

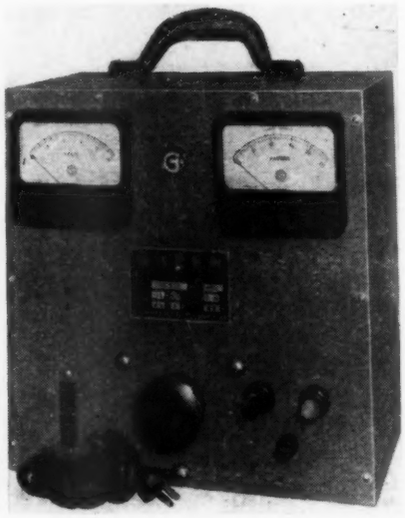


NPT bleed port. In accordance with the requirements for the installation, cutout pressures can be supplied from 300 to 1,500 lb. per sq. in. and the differential pressure can be varied (in relation to the desired cut-out pressure) from 75 to 500 lb. per sq. in. An external adjustment for pressure setting is included.

Rectifier

W. Green Electric Co., Inc., 130 Cedar St., New York City.

Known as Model No. 725 S1C, this rectifier is a complete d.c. power supply source, with a capacity of 150 watts. The cabinet dimensions of the unit are 14 x 14 x 9 in. and it weighs approximately 45 lb. The output is adjustable from zero to 6 volts and has a continuous capacity of 25 amp. The unit is convection cooled, has no moving parts and operates noiselessly. A heavy-duty rubber cord and plug are incorporated to match any standard a.c. outlet; it has an on/off switch of the magnet circuit breaker type, which provides input protection. Panel mounted fuse in the d.c. circuit provides output protection. The unit has a pilot lamp with

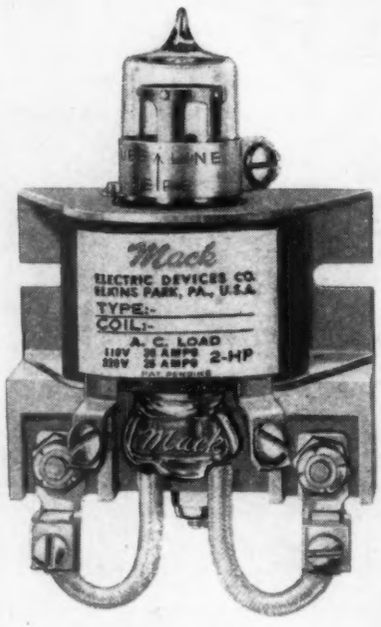


a removable jewel for lamp replacement; a continuous range voltage control transformer, from zero to maximum. A large voltmeter, with an accuracy rating of 2 percent full scale, is connected across the output terminals and a matching ammeter indicates output current. Output terminals are color-coded to facilitate connection.

Control Unit

Mack Electric Devices Co., 507 Township Line, Elkins Pk., Pa.

Known as Mercu-trol, this unit will handle motor loads to 2 hp., 110 volt or 220 volt a.c. and current loads to 35 amp., 110 volts; 25 amp., 220 volts a.c. It is of dust and moisture proof

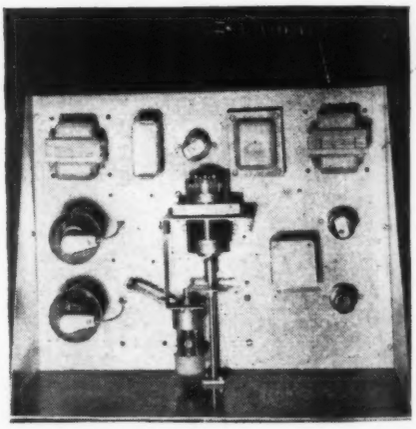


construction with no exposed arc. The tungsten contacts are hermetically sealed, and coil and load terminals are readily accessible. It measures 2⅝ x 4½ x 4¼ inches.

Servo Follow-Up System

Electronic Associates, Inc., 61 Brighton Ave., Long Branch, N. J.

The model 105 system has an output torque of 96 inch-ounces. The same type of equipment can be supplied on special order to control up to ½ h.p. motors. The Model 105 has a maximum following speed of approximately 50 r.p.m. and other speeds can be supplied on special order. The high positioning accuracy of 0.027 percent permits its use in critical measuring systems where remote presentation of measured data such as machine position, water level, dial readings and other data is required. The system can also be used in the reverse direction



to control mechanical movement remotely in any application where a long flexible shaft, without backlash and requiring inappreciable torque, would be satisfactory. The follow-up system serves as a torque amplifier. Since the control mechanism is essentially a shaft, mounted in precision ball bearing without load, practically no power is required to drive the system. Quick heating tubes are used to minimize warm-up time.

Bearings

Kaydon Engineering Corp., Muskegon, Mich.

These four-row nickel-steel bearings are used principally in steel and nonferrous rolling mills on backing and working rolls. Carburized with a deep case, the nickel steel permits thinner cross-sections in heavy duty bearings. This is claimed to result in larger and

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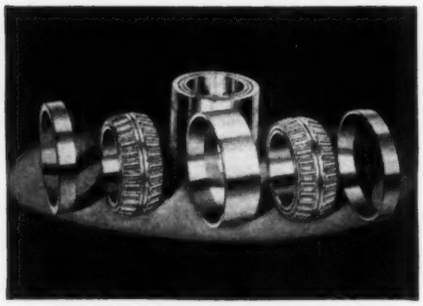


stronger roll necks for a given size mill roll. Other bearings of the straight roller type and 2-row taper type are made of high nickel steel for rolling mills, paper mill calendar stacks and other heavy duty installations.

Combined Motor Pump

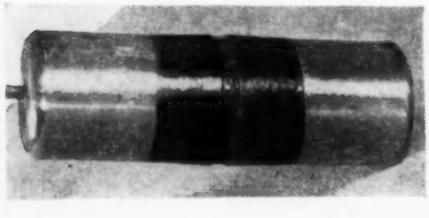
Pezzillo Pump Co., 1343 W. Cumberland St., Philadelphia, Pa.

An electric motor and pumping unit inclosed within a single aluminum alloy housing, pipe-threaded at both ends. The pumping chamber is comprised of a stationary venturi, and an impeller that is attached to and rotates with the tubular rotor. The field windings are permanently sealed and isolated from the pumping chamber. The water passes through the center of the unit to the impeller where by centrifugal action, the pressure is increased and the water driven through the discharge vanes to remove turbulence. The electric motor powering this unit is cooled by the circulating water and by a thermal overload protector matched to the motor characteristics. The combined electric motor and pumping unit is available with pipe sizes ranging from 1 to 2½ in. threaded and with free delivery of 25 to 120 gal. per min.

Mercury Switch

Mercontrol, Inc., 278 Pearl St., New York 7, N. Y.

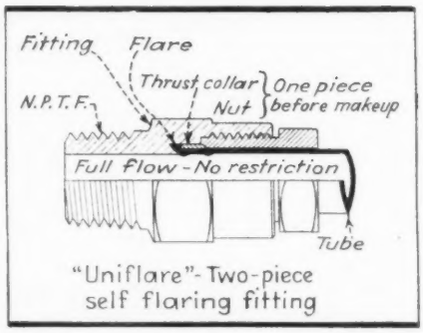
This all-metal switch, Type D-100, is 4-in. long and 1¼ in. in diameter and has a continuous current rating of 100 amp. at 110 volts or 220 volts d.c. or a.c. It can be used in all types of remote control and automatic equipment, and is applicable to tank rheostats of plating equipment where copper switches are exposed to corrosive fumes. At full-load the temperature rise is 25 deg. C. above ambient under normal operating conditions. This switch has been flash-tested with currents as high as 500 amp.



Tube Fitting

The Brockway Co., Naugatuck, Conn.

A two-piece unit for copper, aluminum, Monel, plastic and steel tubing. Plain end tubing is inserted in the fitting and made up in the conventional manner. The tube is self-extruded and self-flared by the wrench action during make-up. The nut, body and thrust collar (which shears from the nut when wrench pressure is applied), combine to produce a smooth, positive action. The nut acts as a ram, the body of the fitting acts as a die and the thrust collar acts as the dummy block and compression member

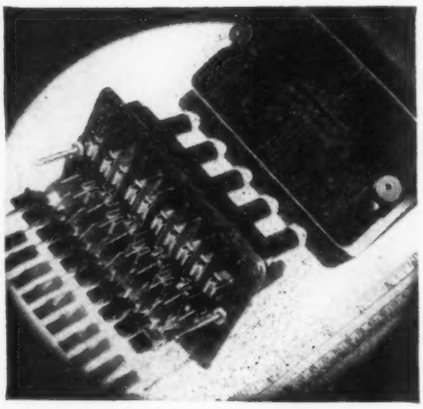


to grip the tube and force it into a 37 deg. flare. The extrusion and coining action of the parts produces a leakproof joint that is reinforced against pressure and vibration; that can be made up innumerable times without damage to the original flared end of tube and without losing its positive seal. Made in sizes ⅛ to ¾ in. in standard commercial shapes.

Test Switch

Westinghouse Electric Corp., Box 868, Pittsburgh 30, Pa.

Designed with up to ten elements and rated at 250 volts, 30 amp., combinations of current and potential switches are included as required for the various types of instruments to be tested. The Flexitest switch is inclosed in a black Moldarta case with cover of similar material that blends well with instruments and relay cases and with panels. Mounting semi-flush on steel

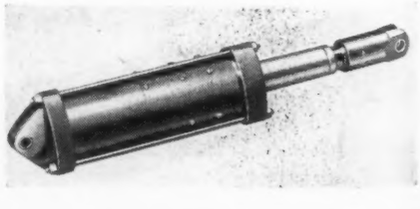


panels of any usual thickness, it is compact and pleasing in appearance. The width is such that it can be mounted on the same centerlines as standard instruments and relays. Individual switches are of the knife-blade type and separated by barriers. Moldarta switch handles are recessed for inserting identification cards. Each switch handle is drilled for insertion of an interlocking bar to tie together any three adjacent handles. The right hand switch, when used for a trip circuit, is provided with a red handle for easy identification. Spring clips can be attached when individual test leads are used instead of a test plug.

Linear Actuator

Electrical Engineering and Mfg. Corp., 4606 W. Jefferson Blvd., Los Angeles, Calif.

The motor and mechanism of this actuator form a completely self-contained unit of simple, compact design, with the only outside elements being three connecting wires. It weighs 11 lbs., 10



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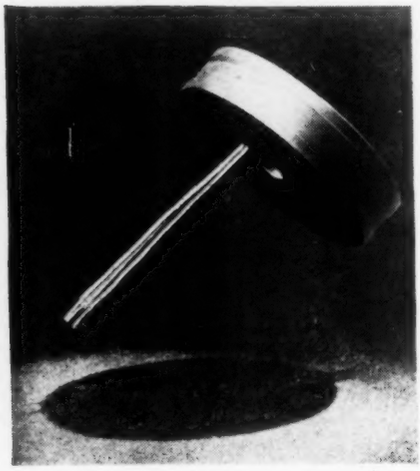
ounces. This electrically operated actuator makes possible, through elimination of tubing, greatly simplified design and assembly, appreciable reduction in weight with consequently increased payload and performance, and important savings in cost of materials, fabrication and assembly.

Lamp Ballast

General Electric Co., Schenectady 5, N. Y.

This disk-shaped, high-power-factor ballast is designed for the operation of two 12 in. Circline lamps. The flat disk construction of this ballast, with

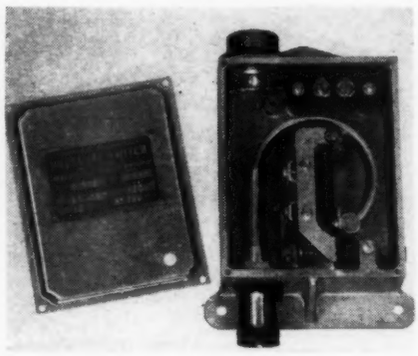


a center hole for mounting, makes it easy to assemble on the stem of a portable lamp or conceal in the lamp base. The ballast leads are brought out through the cover plate and are then threaded through the stem of the fixture for connection to the Circline lamp.

Pressure-Operated Switch

Meletron Corp., 950 N. Highland Ave., Los Angeles 38, Calif.

The Model Series 310 Switch is inclosed in an aluminum case, and can be adjusted externally without removal of cover, or disturbing the mounting. Designed to operate within a range of 20 to 3,000 lb. per sq. in., it is capable of withstanding pressures in excess of the operating range proper, adding a safety factor important in many types of pressure systems where surges and overloads are encountered. All materials used in its manufacture are treated in a manner to make the entire unit corrosion-resistant. Incorporating an Underwriters' Laboratories approved Micro Switch, the unit carries an electrical rating of 10 amp. at 125 volts a.c.,



and can be installed in most industrial systems. The electrical connection is for ½ in. threaded conduit, with screw terminals inclosed within the housing; pressure connection is ¼ in. NPT female thread.

Lubricant

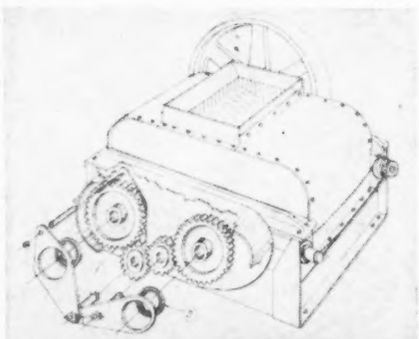
G. W. Smith & Sons, Inc., Dayton, Ohio.

Known as Die Slick No. 11, this lubricant is for pressure die casting dies. It is a colorless, odorless compound that is non-staining, non-corrosive, non-carbon-forming and causes no objectionable smoke or gases. A fine mist spray of the lubricant is applied to the die. It eliminates scoring, sticking and assures easy ejection of the casting. It prevents formation of zinc oxide on the core pins and die cavities. It also leaves no undesirable deposit on the casting that might prove detrimental to subsequent plating of the zinc casting.

Flexible Gear Drive

McNally-Pittsburg Mfg. Corp., Pittsburg, Kan.

Called the Gearmatic, this unit has the driver gear held in position while the driven gear, mounted on a movable shaft, is followed by two floating pinions as it is shifted to new positions. The train operates in a bath of oil, the gear cover acting as a well. The

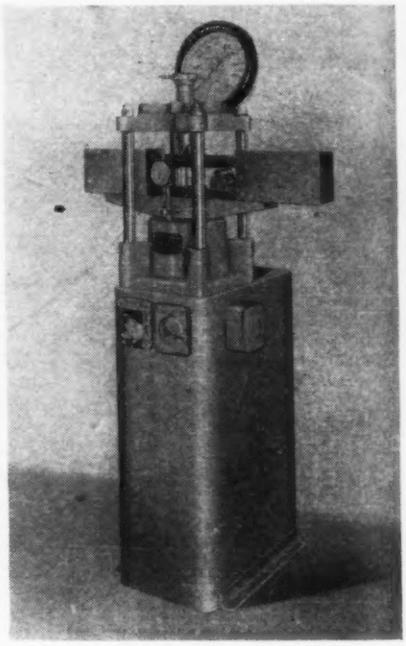


train arrangement is shown in the exploded view. The driver gear is shown at (1). The floating pinions are held in position by two pairs of swinging arms. They ride ball bearings (2), which fit over the gear hubs. The pinions turn on brass bushed pins.

Testing Machine

Steel City Testing Laboratory, 8843 Livernois, Detroit 4, Mich.

A transverse testing machine with a capacity to 10,000 lb. that is hydraulically operated and identified as Model TR-1. The machine is highly sensitive and is adaptable to making transverse



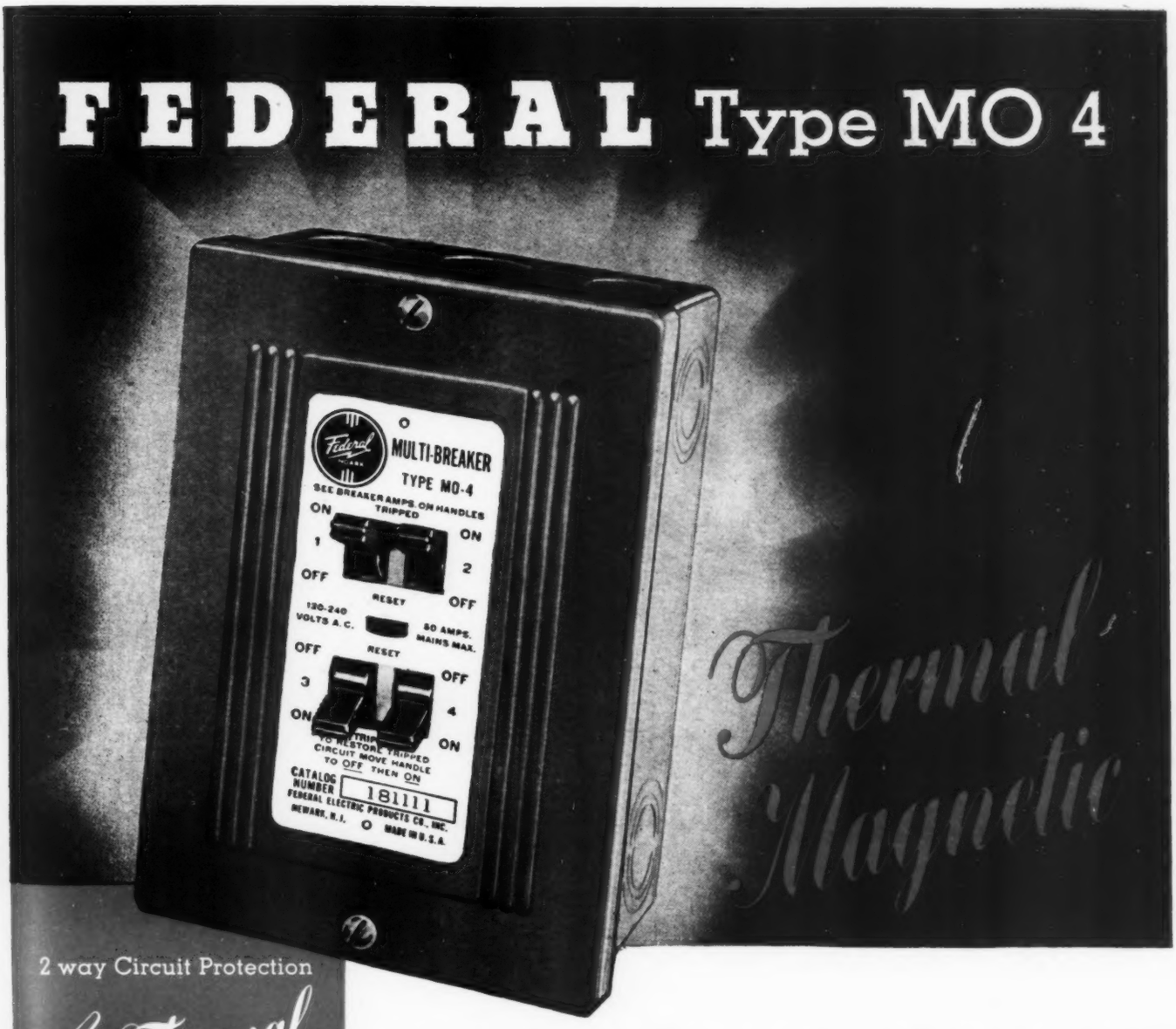
tests with equal accuracy and efficiency on various specimens up to its full capacity. It is easily operated and supplied with electric motor drive at voltages to suit all current requirements. The load is applied automatically. A specially constructed gauge with maximum indicating hand is supplied which remains stationary when the specimen breaks. Gauges can be calibrated in kilogram loads if desired. Specifications, 24 in. maximum span; 4 in. opening; Floor space 26 x 20 inches.

Transformer

General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

Known as the Type V-10 Variacs, these 115-volt models are rated at 10 amp. with a 15 amp. maximum. Designed for the most favorable distribution of cop-

FEDERAL Type MO 4



2 way Circuit Protection

Thermal

Magnetic

MULTI-BREAKER

Magnetic trip operates in a fiftieth of a second or faster, even on minor shorts. *Thermal* bi-metal element provides time-delayed tripping on moderate overloads. That's *THERMAL-MAGNETIC* Protection . . . built into Federal's new Type M04—the smallest, lowest-priced, most efficient Multi-breaker ever produced.

● 4-pole range ● For flush or surface mounting ● Only 5 1/16" x 7 3/16" x 2 7/8" ● Wire ratings 15, 20, 30 amp. ● Ideal wherever two lighting or appliance circuits and a small electric range circuit are needed . . . or where four lighting or appliance branch circuits are needed.

FEDERAL ELECTRIC PRODUCTS COMPANY—Executive Offices: 50 Paris Street, Newark 5, New Jersey. Plants: Hartford, Connecticut; Newark, New Jersey; St. Louis, Missouri.

Federal NOARK

Write for Bulletin No. 154

Federal NOARK INDUSTRIAL CONTROLS

FEDERAL ELECTRIC PRODUCTS COMPANY, MANUFACTURERS OF A COMPLETE LINE OF ELECTRICAL PRODUCTS INCLUDING: MOTOR CONTROLS, SAFETY SWITCHES, CIRCUIT BREAKERS, SERVICE EQUIPMENT, PANELBOARDS AND SWITCHBOARDS

For a reliable drive at many angles!

Photo courtesy of Flexsaw Mfg. Co. Fort Austin, Michigan

HERE'S an idea worth remembering when you have the problem of driving a machine part which must be adjusted to different operating positions. In the circular saw shown above an S.S.White flexible shaft provides a reliable drive for the saw blade while permitting it to be turned and set at any required angle. S.S.White power drive flexible shafts come in a large selection of sizes, making it possible to use this idea on a wide range of requirements.

FOR COMPLETE FLEXIBLE SHAFT DATA

see our catalog in Sweet's File for Product Designers or write for BULLETIN 4501.

S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. DEPT. D 10 EAST 40th ST., NEW YORK 16, N. Y.

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SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
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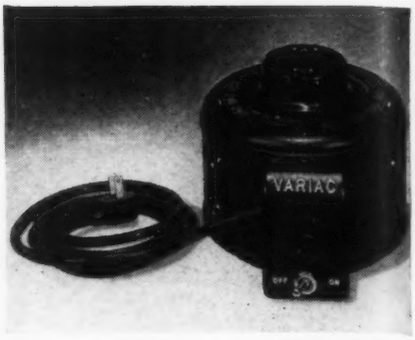
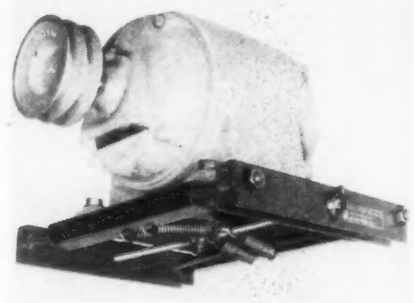


per and iron, with low-loss core material and lightweight structural parts, Type V-10 Variacs have the brush and construction features of the Type V-5, previously announced. The output voltage of these units is continuously variable from zero to 17 percent above line voltage. They are available in 6 models, 115-volt and 230-volt service.

Motor Base

Automatic Motor Base Co., P. O. Box 2186, Paterson, N. J.

Designed for every type of drive and for flat or V-belts, this unit is claimed to insure maximum machine output, fewer shutdowns, and less maintenance. The motor floats against correct spring

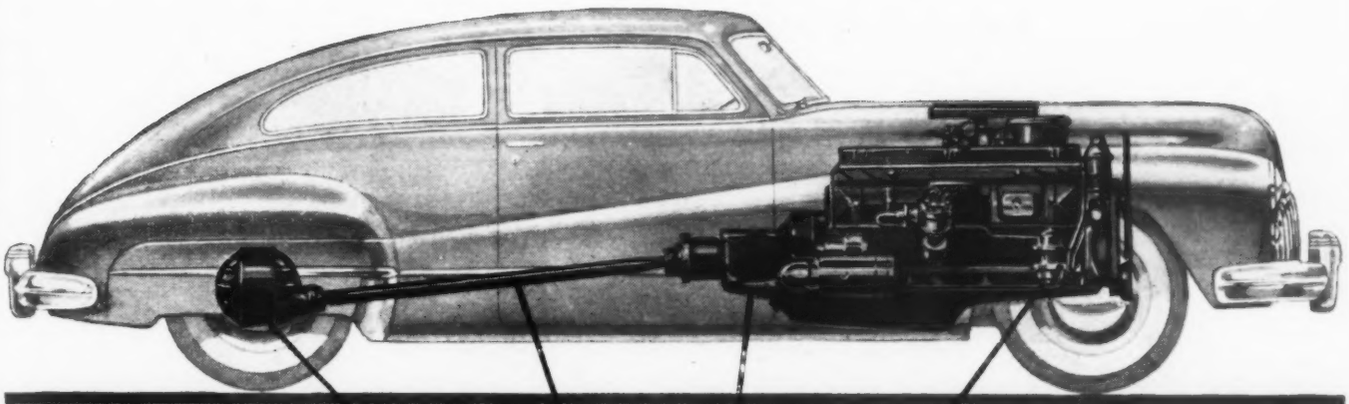


tension so that full and constant power is transmitted to the driven shaft. The motor is secured directly to the base and together they are bolted down as a unit. After the drive is installed and running, the belt tension is adjusted by turning the setting screw. Starting shocks and loads are absorbed by the springs.

Blind Rivet

Cherry Rivet Co., 231 Winston St., Los Angeles 13, Calif.

Blind Rivets available in Monel as well as aluminum, brass and steel. Monel has high strength, ductility and excellent resistance to corrosion. Because of these properties, the Monel rivet is a "general purpose" rather than a "special purpose" fastener. The rivet is identical in construction to other



PARCO LUBRIZING

means

FASTER BREAK-IN • NO SCORING, SCUFFING, SCRATCHING

REDUCES WEAR • SIMPLE, LOW-COST TREATMENT

On wearing surfaces throughout the power train, Parco Lubrizing does an outstanding job. It's a phosphate coating that spreads its own protective, friction-controlling, nonmetallic crystals over pistons, rings, gears, shafts, pulleys, valves, rocker arms. Being slightly porous, it also takes and holds oil as bare metal cannot do.

Parco Lubrizing speeds break-in, guards expensive parts from the dangers of initial scoring, scuffing and scratching. Tests have shown that wear, after the break-in period, is substantially reduced by the Parco Lubrite treatment.

Application of Parco Lubrite is simple, easily controlled, economical. It can be used without affecting parts built to operate at close tolerances.

Investigate Parco Lubrite as a means to overcome *your* wearing problems.

PARKER RUST PROOF COMPANY, 2179 East Milwaukee Avenue, Detroit 11, Michigan

BONDERIZING Holds Paint to Metal

PARKERIZING Inhibits Rust

PARCO LUBRIZING Retards Wear on Friction Surfaces

PARKER PRODUCTS CONQUER RUST

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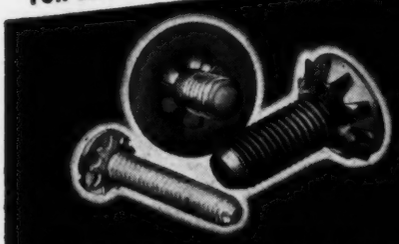
FOR SEMS WASHER SCREW ASSEMBLIES

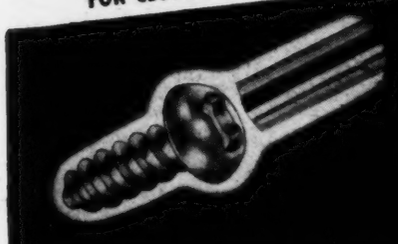


Washer permanently fastened on, yet free to rotate. Easier, faster driving. No fumbled, lost or forgotten washers. Matching finish on both parts. Easier ordering and balanced inventories.

FOR PHILLIPS RECESSED HEAD SCREWS

Increase assembly speed up to 50%! Cut down injuries to workers with no burrs, no skids. Reduce production costs. Reduce rejects! Improve product appearance! Go modern with Phillips!

FOR CLUTCH-HEAD SCREWS



The latest type recessed-head screw. Screw locks on driver. Can't fall off. No screw-driver slippage. Easy to assemble. Exceptional driver life. Ordinary screw-driver may also be used.

FOR SPECIAL COLD-FORGED FASTENINGS

Scovill is expert in cold-forging unusual special fastenings, such as the one shown. Scovill designing ability, engineering skill, men and machines save money for customers. Consult Scovill!

Look at the fastenings you're now using—and see if they're the best for the job. Get better results—at less cost—with modern fastenings. If you use fastenings in *large quantities,* it will pay you to find out what Scovill can do for you. Fill out and mail the coupon below—*now!*

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WATERVILLE SCREW PRODUCTS DIVISION
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- ☐ Scovill Special Cold-forged Fastenings

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COMPANY_____

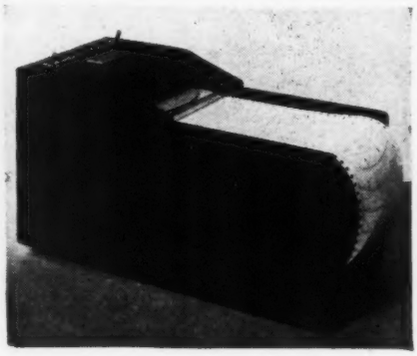
ADDRESS_____

is identical in construction to other blind rivets. It is made in two standard types, self-plugging and pull-through hollow; in the two standard head styles, modified brazier and 100 deg. countersunk; in 1/8, 5/32, 3/16, 1/4, and 9/32 in. diameters; and in a wide range of grip lengths. Other head styles and 7/32 in. diameter are available on special order.

Profilometer Reading Recorder

Physicists Research Co., Dept. 7, Ann Arbor, Mich.

Operating as an attachment to a Profilometer, the reading recorder provides a continuous chart record of the average roughness of the surface being

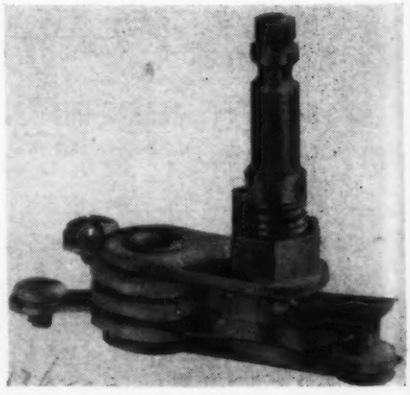


measured. The charts are read in microinches like the Profilometer microinch meter. The recorder attaches at the meter jack provided on the Profilometer. No adaptations of existing Profilometer equipment are necessary.

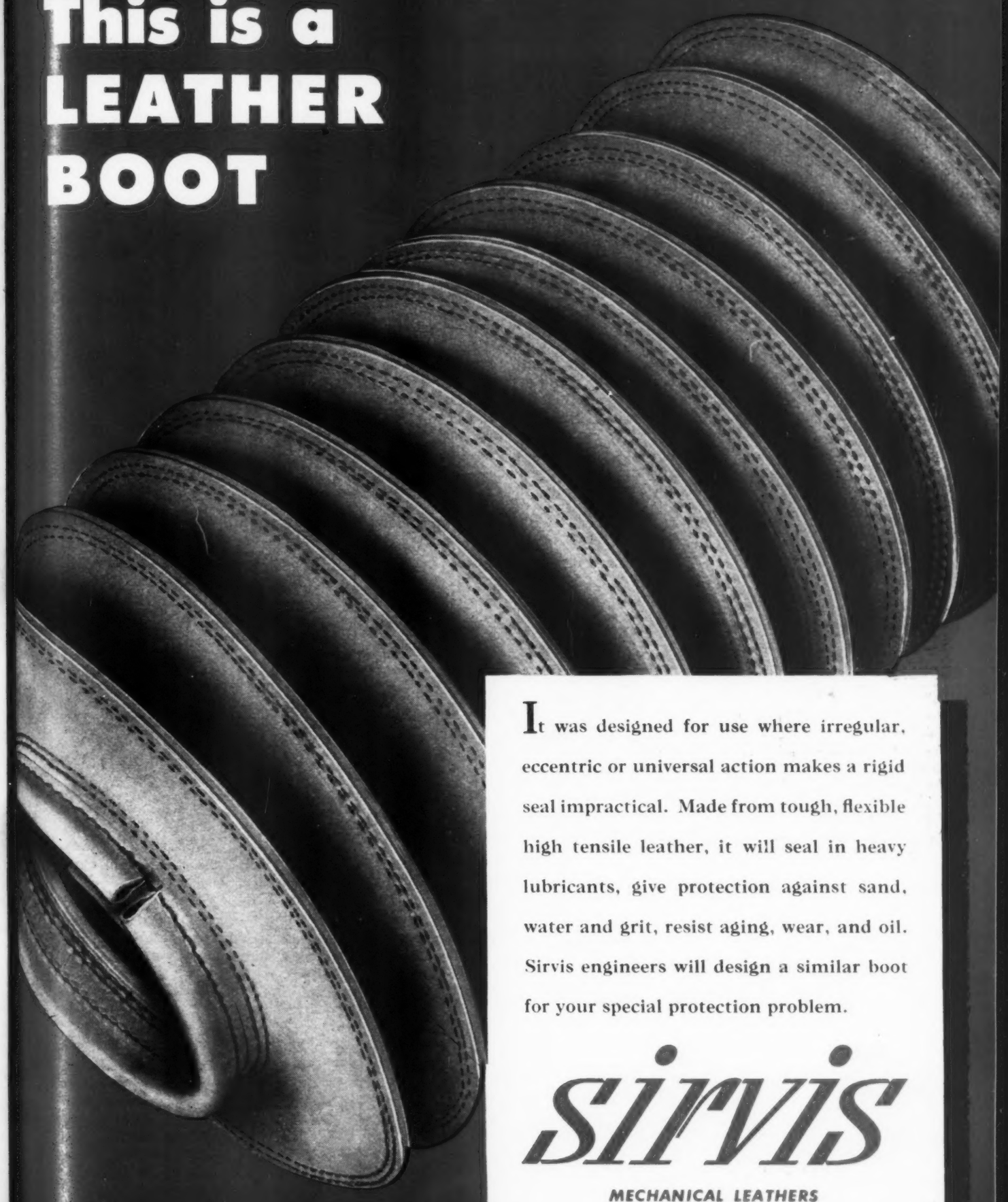
Thermostat

Stevens Mfg. Co., Mansfield, Ohio

Designed for applications requiring close temperature control and long life, the Type S thermostat is pre-calibrated. An independent bi-metal strip actuates the stainless steel or Inconel contact springs, and since the bi-metal carries no operating current, inductive heating of the bi-metal element is eliminated. Heavy-duty silver contacts are spot welded to the contact springs. Ther-



This is a LEATHER BOOT



It was designed for use where irregular, eccentric or universal action makes a rigid seal impractical. Made from tough, flexible high tensile leather, it will seal in heavy lubricants, give protection against sand, water and grit, resist aging, wear, and oil. Sirvis engineers will design a similar boot for your special protection problem.

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How to give metal products the right finish

the efficient economical, sales-building methods that produce more attractive products—

HERE'S a manual which demonstrates the vital importance of the finishing process in the final appearance and sales appeal of a product, and describes each of these processes in careful detail so that you may achieve an attractive finish as efficiently and economically as modern methods will allow. With special attention to improving results and reducing costs, the book covers all types of finish, such as galvanizing, polishing, plating, lacquering, enameling and painting—wood grain reproduction, chromium plating, and synthetic enamels, and many new finishes of a specialized nature.

SUPPLIES UP-TO-DATE INFORMATION ON:

- the techniques involved in metal finishing
- the commercial aspects of metal finishing
- the sales value of attractive finishes
- the economics of metal finishing
- the design of parts which require finishing
- new finishing equipment and processes
- metal finishing costs

Read this partial list of chapter headings for a few of the important processes and topics described:

Sales Value of Attractive Finish
Importance of Color
How to Minimize Cleaning Expense
Pickling for a Better Finish
Polishing in Industry
Designing Products to Reduce Polishing Expense
Recent Developments in Plating
Chromium Plating
Spray Coating
Electroplating Costs and Estimating
Synthetic and Novelty Finishes
Enameling and Lacquering
Coloring Aluminum
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FINISHING METAL PRODUCTS

By Herbert R. Simonds, *Consulting Engineer,* and Adolph Bregman, *Consulting Engineer. 352 pages, 5¼ x 8¼, 147 figures, $4.00*

THE revised edition of this highly useful manual describes the many new developments which have taken place during the war, and incorporates the rapid progress in plastic and synthetic resins. New chapters on coloring metal, on costs and estimates and on organic coatings have been added. Answers to every kind of question which arise in connection with the finishing processes are supplied in careful detail, aiming as the most efficient and economical means of achieving a highly attractive finished product with a maximum of selling appeal.

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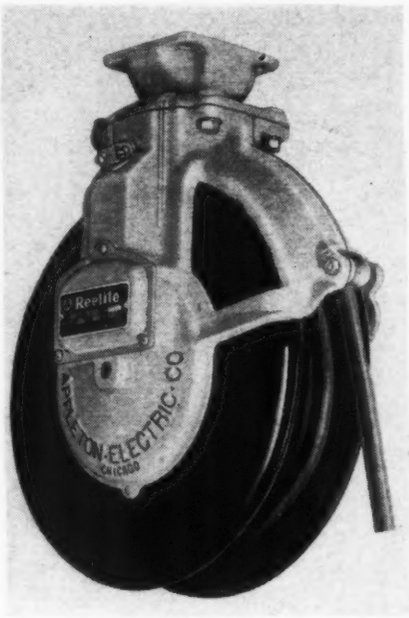
mostat units can be supplied with either lava or mica insulation. A single through hole provides for quick mounting with either screw or stud. The Type S thermostat is supplied with either standard or elevated terminals. Heating capacity of the adjustable thermostat is listed as 15 amp., 115 volts a.c.

Cable Reel

Appleton Electric Co., 1701-59 *Wellington Ave., Chicago* 13, *Ill.*

This reel automatically takes up and pays out conductor cable. It serves any stretch of track. For curved track,

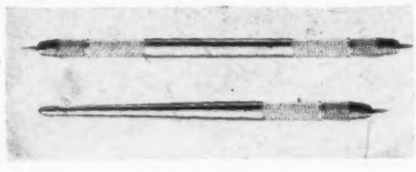


and certain straight track installations, the Reelite is furnished with swivel base, permitting rotation up to 335 deg. Conductor cord is kept gently taut at all times, spring controlled reel takes up or pays out cable in harmony with movements of the hoist. Safety grounding through an extra conductor prevents electrical mishaps.

Drafting Pencil

Elastichuck Sales Co., Inglewood, Calif.

This unit has a rubber collet in the neck of the chuck which grips the lead and "cushions" it against undue pressure. The rubber collet is the only contact between lead and pencil. The hardened steel chuck cannot be damaged when sharpening leads against a



On this 300 ton Warco Eccentric Gear Press, with pneumatic die cushions in bed, Colgate deep draws parts using blanks up to 44" x 70" to a 10" depth.

Add these facilities

for volume forming and stamping of metal

Without Increasing Overhead!

To buy the machinery and build the additions to your plant necessary for sheet metal forming, stamping and fabricating would cost—how much? Yet you can add this extra function *without adding to overhead*—by making Colgate your "sheet metal department."

Colgate has complete facilities—up-to-date forming and stamping equipment, experienced labor, and plenty of working space—for the precision manufacture of production parts and even complete units *in quantity*.

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If you have a "tough" assembly to produce in volume, or are merely pressed for time or space, call in Colgate. Specialists in the light metals, and geared for mass-production, Colgate will *deliver the goods* on time (or ahead of schedule) and, more than likely, at a lower cost than you could handle the job if you had a sheet metal department of your own.

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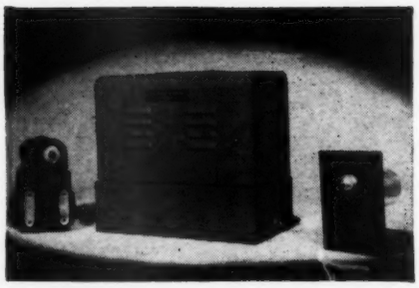
LIGHT METALS PRODUCTS

file or sandpaper pad. The chuck and barrel are knurled for normal grip and tapered for perfect balance. Metal is highly polished, will not stain or rust. A roll-stop keeps pencil from rolling off inclined drawing boards. Elastichuck pencils use all standard drawing leads; an indexed tip identifies the lead in the pencil. Pencils are available either in single-end or double-end. Double-end pencils will accommodate two full-length leads and are used where two kinds of leads or colors are necessary.

Remote Control Servomechanism

G. C. Wilson & Co., 2 N. Passaic Ave., Chatham, N. J.

Servo for remote indication or control. The servo consists of three units: Torque unit, amplifier unit, and control unit. The position of the shaft on the torque unit is controlled by the amplifier to correspond to the control unit. The system is sensitive to 1 percent changes in the control unit which requires approximately 1 ounce-inch of torque for operation. The torque unit develops a maximum of 50 lb. ft. of torque. The amplifier unit consists of three radio-type vacuum tubes and associated equipment. A safety feature



is provided in the signal light associated with control unit which indicates correct operation of system. The system operates from 115 volt 60 cycle power which is supplied at the amplifier.

Electrical Conduit

The American Brass Company, Waterbury 88, Conn.

Known as "Sealtite," this flexible conduit excludes moisture and oil from electrical wiring on machine tool equipment, and is claimed to meet the latest requirements of The National Machine Tool Builders Association. "Sealtite" conduit is made of a galvanized steel flexible tubing covered with an oil-proof synthetic material. Conduit fittings are standard pipe thread, and are available in two styles; either permanently attached at the factory, or ready for assembly on the job. The conduit is made in all standard sizes to 2 in. I.D.

Wire Mesh

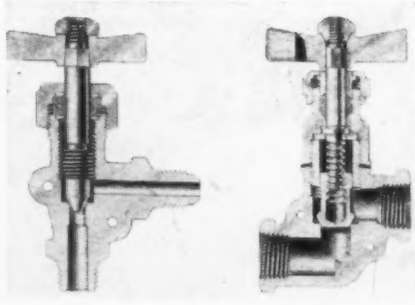
The C. O. Jelliff Mfg. Corp., Southport, Conn.

Lektromesh is a one-piece solid metal product, with no woven or other foundation structure; it cannot ravel and is resistant to tearing. The product supplements woven wire and is most applicable in the finer sizes beyond the limits of perforated metal, and where applications differ from those of woven wire of comparable mesh size. Hole diameters are accurate and the screen presents a smooth surface finish equal to that of perforated mesh. It is stiff, strong and wear-resistant, and is readily fabricated by drawing, stamping, welding, soldering, and other secondary operations. A wide variety of mesh patterns can be produced in various metals. Meshes produced vary from 40 to 400 mesh.

Industrial Valves

Parker Appliance Co., 17325 Euclid Ave., Cleveland, Ohio.

Available in needle and globe types in sizes up to 1 in., and in both angle and offset designs, these units are unusually compact. Both the needle and shut-off types are available in six variations of connections arrangement. Straight-line types are produced with female pipe threads, or with tubing threads for the use of flexible tubing. Angle types are provided with female pipe threads, with tube threads, or with male threads at the inlet connection and either tube or female pipe threads at the side outlet. The valves can be directly connected into either pipe or flexible tube systems without the neces-



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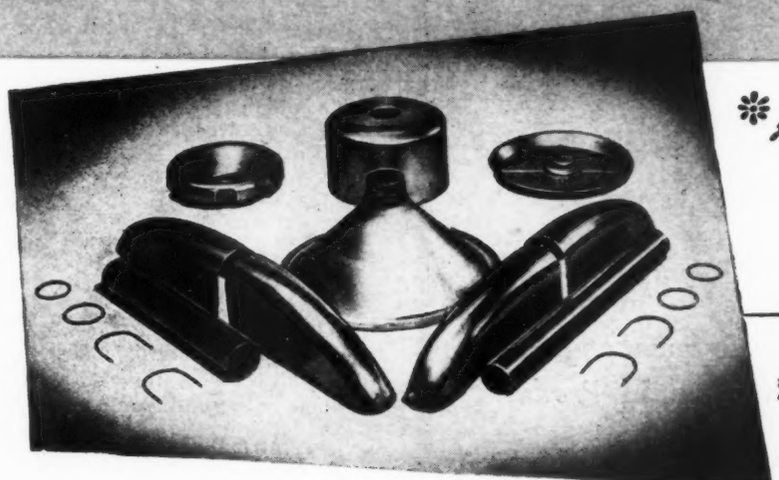
BULLETINS giving all the facts will be mailed on request. Write for them today.

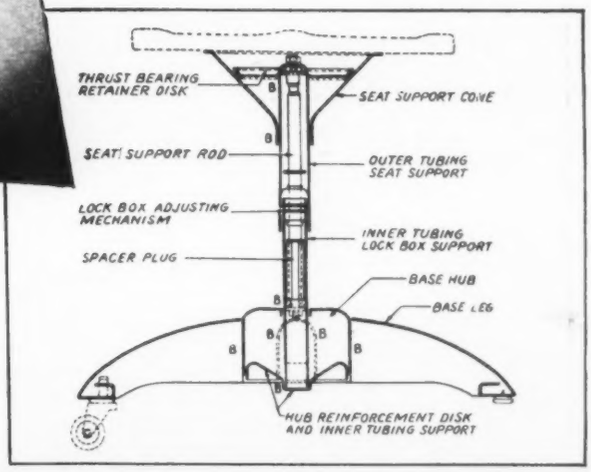


Above are the makings of the chair—8 steel stampings, 2 pieces of steel tubing, and four rings and four U-shaped pieces of 3/64" EASY-FLO wire which join them. Assemblies with the alloy preplaced are positioned and held in simple fixtures for brazing with gas-air burners. Letter B marks the location of brazes. *Production—50 chairs an hour.*

*A Typical Example

STEEL CHAIR FOR STENOGRAPHIC AND INDUSTRIAL USE

Designed and Produced by
Kewaunee Mfg. Co., Adrian, Mich.



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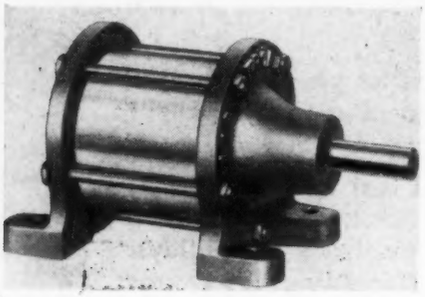
sity for extra nipples, or adapters. Tubing is accommodated in a range of from ¼ to 1 in. outside diameter, pipe from ⅛ to 1 in. All valves in the series are provided with integral mounting lugs for convenience in securing valves to brackets or panels to insure long-life, leak-proof connections in installations where vibration is a factor. Bolt holes are drilled to accommodate standard-size bolts.

Air-Control Cylinder

Air-Trol, 2651 W. Lake St., Chicago 12, Ill.

These cylinders feature true-bore cylinders, non-rusting cylinder heads, oilless (graphite impregnated) bronze ram bushings, and precision assembly.

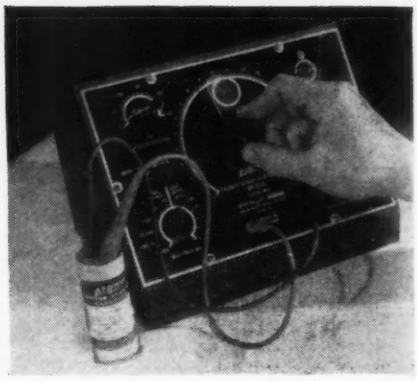


Sizes range from 1½ in. up; power factor from 1.76 times air line pressure. Designed for single or multiple (production line) setups. Foot control is available as supplementary equipment.

Resistance-Capacitance Bridge

Aerovox Corp., New Bedford, Mass.

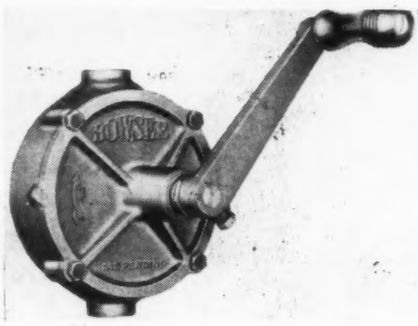
The Model 76 has a 4 in. dia. dial with the same calibrated and linear scale for all functions. Both resistance and capacitance readings are covered by six overlapping ranges and the "magic eye" null indicator provides the indication of balance. The Model 76 bridge: (1) Measures capacitance from 100 to 200 mfd. in six ranges; (2) measures resistance from 10 to 200 megohms in six ranges; (3) measures power factor from 0 to 50 percent; (4) provides d.c. polarizing potential for leakage measurements, from 0 to 600 volts d.c., continuously variable and calibrated in volts; (5) checks leakage of electrolytic capacitors or insulation resistance of paper or mica capacitors. The instrument is provided with shock-proof color-coded test loads fitted with banana plugs for the panel jacks, and with clips at the other end.



Rotary Hand Pump

Bowser, Inc., Fort Wayne, Ind.

This unit has a capacity of 10 gal. per min. at a normal cranking speed and is of the vane type with an aluminum rotor, graphite carbon vanes, and stainless steel springs. Suction and discharge ports are threaded for ¾-in.

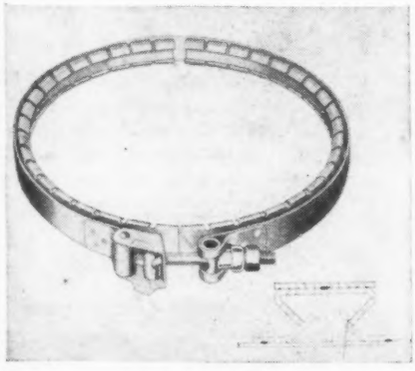


iron pipe. The rustproof working parts are claimed to eliminate the "freezing" action of rust due to condensation within the casing when the pump is not used frequently.

Manifold Coupling

Manman Products Co., Inc., 940 W. Redondo Blvd., Inglewood, Calif.

A new high temperature unit that affords a positive seal for all types of manifold joints operating under condition of high temperature and excessive vibration. Wedging action of the retainer ring draws together the flanges of the manifold joint as the coupling is



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Mechanical, Chemical, Organic and Electrolytic Treatments

A survey of the various types of finishes for aluminum, by a prominent development engineer in the field. This article appeared in *Product Engineering*, November 1946.

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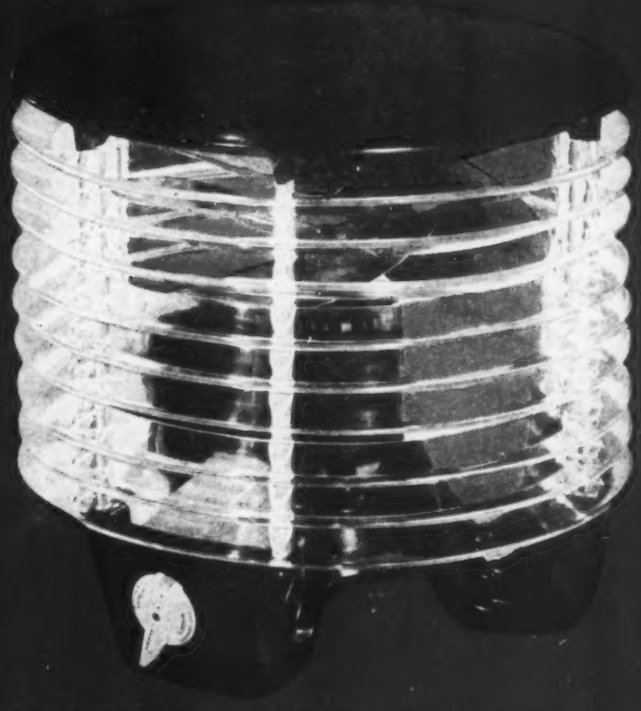

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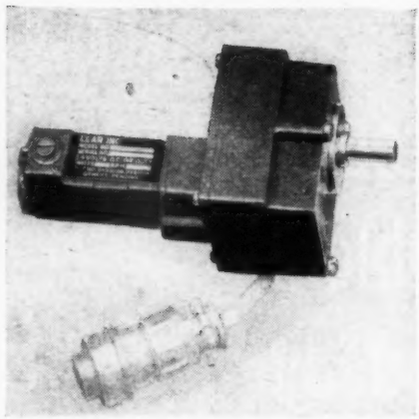
tightened. High axial component of the clamp band tension that is transmitted into weldging action provides a positive seal. The vented construction of the retainer ring makes it possible for the coupling to remain at one-half the temperature of the manifold, giving an increasingly positive seal as the temperature of the manifold rises. Any manifold equipped with machines or rolled flanges similar to cross-sections shown can be efficiently joined with this coupling.

Actuator

Lear, Inc., Grand Rapids, Mich.

Known as the Model 182 series rotary actuators, these lightweight units have an overall length of approximately 5 in., with worms, worm gears, and helical gears housed in a compact shell to make up the reduction gearing. The Lear "A" or "G" frame motor with integral electro magnetic disk-type brake insures precision control. Control equipment is extremely flexible. A multiple non-reversing rotary limit switch can be incorporated for any number of positions up to 16. Multiple reversing rotary limit switches can be incorporated for any number of

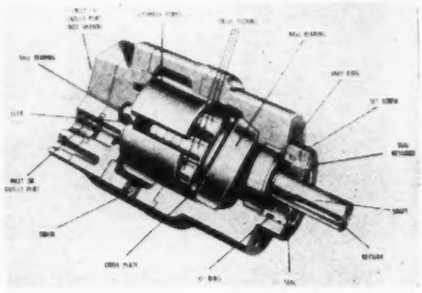


positions up to 8. Weight range of 182 series actuator varies from 1.25 to 1.75 lb. Torque output rating, depending on combination of motor size and overall gear reduction, varies between 15 and 65 lb. in.

Fluid Motor

Denison Engineering Co., Columbus, Ohio.

This fluid motor of axial piston design is available in 3 and 5 h.p. capacities; with or without a speed control valve; with or without a choice of geared-head units of various gear ratios; and with a selection of brackets for mounting the motor with equal operating efficiency in any position desired. The motor proper has a "floating drive," wherein constant pressure contact is maintained between the driving and driven elements without the use of mechanical linkages or connecting rods of any kind. The motor is fully self-starting; operates equally efficient in either direction; can be instantaneously reversed, and is completely self-lubricating. When equipped with the speed control valve this fluid motor can be pre-set to operate at any speed within its capacity. Infinite speed variations are obtained by the adjustment of a knurled knob on the side of the valve. A plunger device interlocked with the

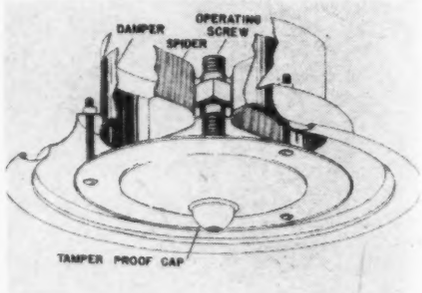


speed control valve permits instant acceleration from any pre-set speed to full speed whenever desired, to meet any rapid traverse requirements. When plunger is released, the motor returns at once to its pre-set speed. This plunger device can be controlled by lever, cam or any other arrangement the user may prefer setting up. If the motor is used without a speed control valve and is powered by an independent pumping unit, the speed can be regulated by adjusting the volume of oil delivered to the motor.

Air Damper

W. B. Connor Engineering Corp., 114 East 32nd St., New York 16, N. Y.

Designed as a standard accessory of Kno-Draft high velocity air diffusers, this cylindrical damper is raised or lowered by turning the extended shank of the operating screw, centered in the lower cone and concealed by the tamper-proof cap. Any air volume can be



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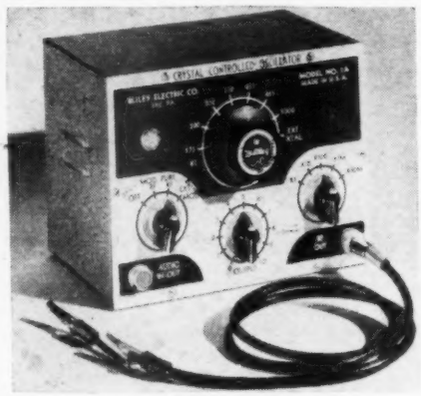
obtained, furnishing the flexibility which is an important factor in rapid system balancing. As the damper is an integral part of the diffuser, no additional installation time is required on the job. The damper operates independently of the lower cone which is dropped or raised to adjust the air flow direction.

Crystal-Controlled Oscillator

Bliley Electric Co., Erie, Pa.

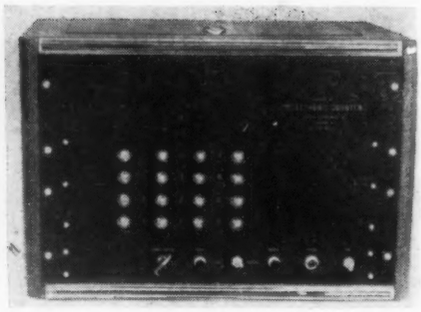
Known as the CCO, this unit utilizes low temperature coefficient quartz crystals, stable to within plus or minus 0.1 percent to provide direct crystal control, with instant selection, of the five most commonly used intermediate frequencies: 175 kc, 262 kc, 370 kc, 455 kc and 465 kc. Direct crystal control is also provided at 200 kc for r-f alignment and at 1000 kc. for short wave alignment. An external socket is provided to accommodate special frequencies that may be required. A three position modulation selector and a five step attenuator with vernier output control from 0 to 15 volts provide finger-tip operation. Power consumption is 17 watts at 110 volts a.c. or d.c. No warm-up period is necessary since the crystals are on frequency as soon as the oscillator is energized.



Decimal Scaling Circuit

Potter Instrument Co., 136-56 *Roosevelt Ave., Flushing, N. Y.*

Known as the Model No. 85, this unit is designed to respond to pulses occurring at rates as high as 100 kc. per sec. By a simple plugging operation it is possible to obtain scaling factors of 10 to 1, 100 to 1, 1000 to 1, or 10,000 to 1. Higher scaling factors are available in other models. Four 4-tube decades are employed in the Model 85. These decades are of standard design. The four decades are included with input shaping circuits and power supply. Power consumption is 150 watts at 115 volts, 60 cycles.



Solvent Cleaner

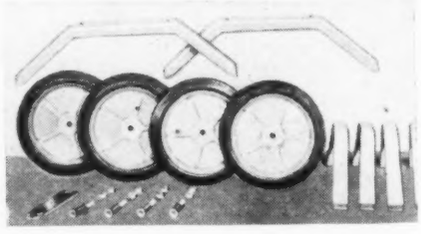
Enthone, Inc., 442 *Elm St., New Haven, Conn.*

A type of emulsifiable solvent cleaner designated as Emulsion Cleaner EC-75. This product is recommended for the removal of oil, buffing compounds and other organic dirt, as well as solid dirt, from all types of metals including active metals such as zinc, aluminum, brass and nickel silver. This product will not harm alkali cleaners when it is dragged into them, and it is claimed to actually increase the cleaning ability of alkali cleaners. Emulsion Cleaner EC-75 is used undiluted. The material is a penetrating solvent to replace naptha, kerosene and chlorinated solvents and, in addition, it has high detergency and emulsifiability.

Utility Wheels

The Palmer Mfg. Co., 8115 *Clinton Rd., Cleveland, Ohio.*

These units have a specially designed, patented mounting device that utilizes no cross axle and does not limit width or stability in vehicle design. The solid rubber tires are specially mounted to eliminate tire loosening or slippage at rims. Wheels are sold in 8 and 5½ in. diameters either in sets of four with stamped steel assembly fixtures included; or as individual wheels with both ½ and ⅜ in. bushings.



Air Cylinders

The Fern Mfg. Co., Hartford, Conn.

Where space is at a premium in the design of a machine, these cylinders can be built to conform to the limitations of the design without altering the power

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The wand in the welder's hand is a shielded arc electrode made of Riverside *Phosphor Bronze.* It is manufactured by one of Riverside's customers, whose name has been synonymous with scientific achievement in arc welding for more than forty years. Almost like a magic wand, the electrode, when properly employed unites copper, brass and many types of bronzes which are difficult to braze.

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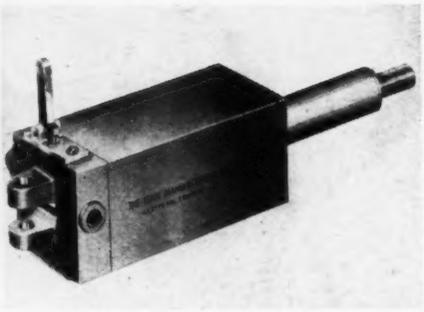
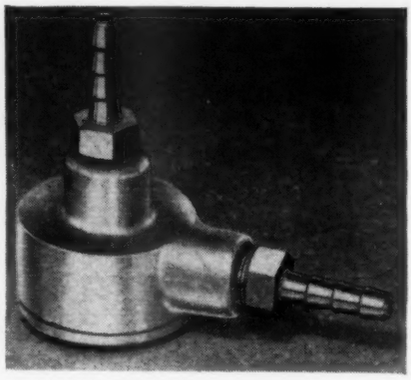


or the available pressure. All unnecessary packing is eliminated, thus reducing friction loss and maintenance costs, while adhering to design specifications. Built to provide accurate control of the piston velocity curve according to needs, the cylinders can be cushioned at either or both ends of the stroke. Complete cylinder valve can be furnished as a separate item or as an integral part of the cylinder. Furnished in three types for air economy; single-acting; double-acting; and differential-acting.

Exhaust Valve

Mead Specialties Co., Dept. Dept. E. V., 44, 4114 N. Knox Ave., Chicago 41, Ill.

This unit automatically opens as soon as the air supply is shut off, thus speeding up the return stroke of air cylinders. It can be attached directly to air

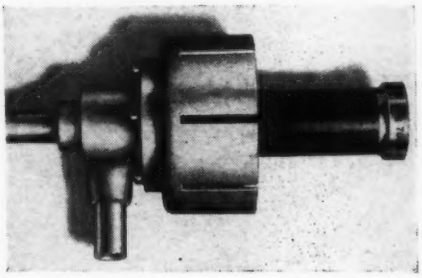


cylinders with a ¼ in. pipe nipple, or cut into the air hose adjacent to the cylinder. Overall dimensions, exclusive of nipples, are: Body diameter, 1 3/5 in.; height, 1½ in.; length, 2¼ in. Both nipple openings tapped ¼ in. N.P.S.

Water-Cooled Resistor

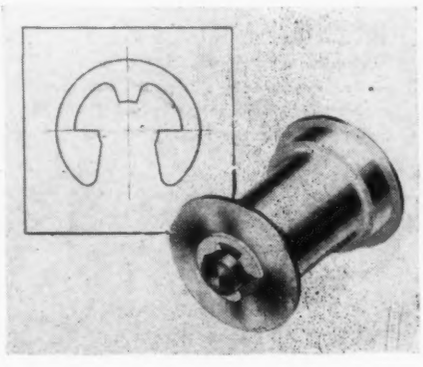
International Resistance Co., Philadelphia, Pa.

The Type LP liquid-cooled high frequency-high power resistor has a high velocity stream of water flowing in a spiral path against the resistance film. Through centrifugal force, this flow maintains intimate thermal contact with the entire surface. Interchangeable intake nozzles permit adjusting the rate of water flow and therefore, the cooling action, to suit local water pressure and power dissipation up to 5 kw. A resistance film less than 0.001 in. thick, with an active length considerably less than ¼ wave length at FM and television frequencies, gives good inherent frequency characteristics. Designed to permit direct mounting on the end of a coaxial line with both water intake and outlet connections at RF ground potential. Resistance elements are in-



terchangeable and made to order for range and tolerance. The LP resistor is available in values of 35 ohms to 1500 ohms. Resistance tolerance: ± 15 percent standard, with tolerances of ± 10 percent and ± 5 percent available at increased cost. Different values and service replacements can be readily installed in the field.

Retaining Ring

Waldes Kohinoor, Inc., 47-10 Austel Pl., Long Island City 1, N. Y.

An "E"-shaped ring for small shafts. Providing a large and uniformly protruding shoulder on shafts of 3/32 in. diameter and over, this ring, sprung into a comparatively deep groove, is designed to withstand high thrust loads. Three protrusions, equally spaced, form the abutments in the groove of the shaft. Recesses between the protrusion make the ring sufficiently resilient to permit the necessary spread for assembly and disassembly without permanent set. Installed in a radial direction requiring no special tools, the "E" ring is suited for application where a shaft is inaccessible in a longitudinal direction.